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ABSTRACT

GRADES OR AGES: Grades 11 and 12. SUBJECT MATTER: Electrical technology. ORGANIZATION AND PHYSICAL APPEARANCE: The guide is in two volumes. The first volume gives a brief outline of the course, breaking it down into divisions, units, and subunits. The second volume gives a detailed description of each subunit in a seven-column layout across two pages. The first volume is offset printed and staple-bound with a paper cover; the second volume is offset printed and edition bound with a soft cover. OBJECTIVES AND ACTIVITIES: General objectives for the course are outlined briefly in the first volume. Each subunit description in the second volume lists several activities and teaching tips. A letter coding classifies each activity as experimental, problem-solving, application study, or project. An introductory section presents several different methods for organization and timing of the units and subunits. INSTRUCTIONAL MATERIALS: No mention. STUDENT ASSESSMENT: No mention. (RT)

ONTARIO DEPARTMENT OF EDUCATION

CURRICULUM S-27B

ELEMENTS OF ELECTRICAL TECHNOLOGY

GRADES 11 AND 12

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FOREWORD

An integrated technical course is one in which two or more disciplines that have common or complementary content are combined into one technology. This course outline in Elements of Electrical Technology represents an integration of subject content in the electrical field. The outline consists of three Divisions: Theory and Test, Electronics, and Installation and Maintenance. It is intended for use in Grades 11 and 12.

At the secondary school level, we are concerned with fundamentals rather than the treatment in depth which characterizes the tertiary levels of education. An integrated approach is desirable because students understand basic principles best if they are able to relate them to several subjects. The relation of various technical subjects to mathematics, science, English and history should be stressed repeatedly. In this way the technical subjects become effective educational vehicles as well as a means of learning skills.

Since the course is a two-year entity, the teachers must decide the extent to which any unit will be studied in either Grade 11 or Grade 12. Although the arrangement of the outline is logical, it is not chronological: it is an analysis of subject content, not a synthesis. *No attempt has been made to arrange the topics in a teaching sequence nor has any attempt been made to integrate the topics of the three divisions*: these tasks are reserved for the professional teacher. The need for frequent consultation among the participating teachers is imperative. If possible, one or two periods per week should be set aside so that course construction, lesson planning, and evaluation can be pursued as a team effort.

The course outline was prepared on the understanding that a total of six hundred hours was available for implementation: of this time allotment, about thirty-five per cent should be devoted to Division 1, forty per cent to Division 2, and twenty-five per cent to Division 3. Teachers may alter these ratios somewhat, and may omit optional topics (marked "O") in favour of other material.

Approximately sixty per cent of the available time should be devoted to student activity that reinforces theoretical aspects. The teacher may, however, increase this ratio by developing individualized, imaginative methods. The inductive, directed-discovery approach should be implemented as frequently as possible.

Since Division 1 forms a common core for the entire course, any participating teacher may present any portion of it. In order to avoid duplication of effort, teachers must collaborate on a regular basis: the vertical or chronological sequence is the responsibility of the instructors who are presenting the course.

Students should feel that they are taking *one* technical subject. This may be accomplished by innumerable arrangements and varieties of presentation. To illustrate the manner in which a given topic relates to sections in all divisions, one might consider Transformers (Section 17.1). Without any selection as to sequence or to depth of treatment, Transformers can be related to the following:

11.1	Direct current
11.2	Magnetism
13.1	D.C. generators
15.1	Alternating current
15.2	Inductance
16.1	Three-phase fundamentals
17.3	Three-phase induction motors
21.5	Transformers (electronic components)
23.1	Power supplies
23.2	Circuits using amplifying devices
24.1	Audio amplifiers
24.3	Radio transmitters and receivers
34.4	Transformer installations
34.5	Transformer protection
34.6	Transformer testing and maintenance
35.5	Reduced voltage starters

This list illustrates the fact that the course outline offers an organization of content, but does not inhibit teachers from developing a coherent sequence related to the particular requirements of their classes and the facilities at hand.

AIMS AND OBJECTIVES

The primary aims of technical education are identical with those of education as a whole: developing each student's personality and capabilities, and giving him constructive attitudes towards himself and society.

Any technical curriculum should be such that (1) it provides a sound educational base from which further education or training may proceed, (2) it prepares for employment by the development of basic technical skills.

The specific objectives of Elements of Electrical Technology are to develop the student's ability to:

- Comprehend the impact of electrical technology upon an industrialized society
- Define his vocational goals within the electrical and electronics industry
- Understand the principles upon which the operation of electrical and electronic apparatus depends
- Use simple mathematics pertinent to electrical theory, and interpret such mathematical expressions in terms of physical realities
- Prepare coherent, orderly laboratory reports
- Do independent research for technical information from various sources
- Appreciate and practise sound safety procedures
- Assume responsibility, and work independently of supervision
- Interpret service information and use it intelligently
- Relate schematic diagrams to actual circuitry
- Select and utilize a wide variety of electrical measuring equipment
- Diagnose faults, and service a diversity of electrical equipment, working from first principles.

SAFETY

The responsibility for safety consciousness rests with the teachers of Elements of Electrical Technology. Not only should they describe potential dangers and possible unsound procedures clearly before any practical student activities, but they must also lead students to "think safety" at all times.

Representatives of recognized industrial safety organizations should be invited to inspect the technical department shops in order to assess equipment and routines. In addition, these representatives might be asked to speak to students and/or teachers on modern safety practice.

ORGANIZATION

DIVISION 1: THEORY AND TEST

Units 1.1 Fundamentals of Electricity and Magnetism
1.2 Electrical Measurement
1.3 D.C. Machines
1.4 D.C. Motor Controls
1.5 Single-phase Circuits
1.6 Three-phase Circuits
1.7 A.C. Machines

DIVISION 2: ELECTRONICS

Units 2.1 Standard Electronic Components
2.2 Electron Devices
2.3 Basic Electronic Circuits
2.4 Electronic Systems
2.5 Test Equipment
2.6 Servicing and Test Procedures
2.7 Construction Methods and Techniques

DIVISION 3: INSTALLATION AND MAINTENANCE

Units 3.1 Trade Requirements
3.2 Ontario Electrical Code
3.3 Electrical Wiring Systems
3.4 Distribution Systems
3.5 A.C. Motor Controls
3.6 Electrical Maintenance

DIVISION 1: THEORY AND TEST

INTRODUCTION

This division should be considered basic to the entire course. The concepts and principles relating to circuits, components, and machines will constantly serve as a foundation for the study of Divisions 2 and 3. This is not to imply that Division 1 should be taught as a whole, but rather to indicate that portions of it should be introduced prior to related studies in other divisions. The teacher must determine the exact chronological sequence of the material in a manner which he considers to be most viable in an educational sense. This arrangement of content should, as far as possible, involve student activities that can be described as "learning experiences". To achieve this, a program less rigidly structured than the traditional should be considered.

The emphasis in Division 1 should, for the most part, be on underlying principles, not on hardware or its manipulation. The studies can be used to realize many of the objectives listed in this publication. The related science and mathematics should be integrated with the electrical theory, as the latter is studied within the shop or laboratory. This integration will be furthered by discussions among technical subject teachers and those responsible for instruction in English, science, and mathematics.

The discipline of Elements of Electrical Technology relates to the control of the electron; therefore, a description of the properties of the electron is a logical beginning. All electrical phenomena may be interpreted in light of an understanding of electron behaviour. Students should become able to anticipate this behaviour under various conditions, i.e., hypothesize to a limited extent.

Many illustrations from industrial equipment and practices will serve to emphasize the need for a broad background in the electrical field. The teachers can reinforce this point by arranging plant tours, and by the use of good films and other reference material. In addition, the students' opportunities for education at the tertiary levels will be enhanced by the comprehension of fundamentals. In this regard, the subject content of Division 1 provides a vehicle for formative learning and experience.

UNIT 1.1

FUNDAMENTALS OF ELECTRICITY AND MAGNETISM

Direct Current

Electron Theory
Electrical Charges
Methods of Producing EMF
Electrical Circuits
Electrical Conductors and Insulators
Electrical Power and Energy

Magnetism

Theory of Magnetism
Magnetic Fields
Magnetic Properties of Materials
Electromagnetism
Magnetic Circuits

UNIT 1.2

ELECTRICAL MEASUREMENT

D.C. Instruments

D'Arsonval Movement
Instrument Reading
Series ohmmeter
Insulation Tester

A.C. Instruments

Rectifier Instruments
Multimeters
Moving Iron Instruments (O)
Electrodynamometer (O)

Electrical Bridges

Wheatstone bridge
Introduction to a.c. bridges

UNIT 1.3

D.C. MACHINES

D.C. Generators

Electromagnetic Induction
Single Loop Generator
Construction and Internal Connections
Self-excitation
Operating Characteristics
Commutation

D.C. Motors

Motor Principle
Construction and Internal Connections
CEMF
Operating Characteristics
Efficiency of D.C. Machines
Dynamic and Regenerative Braking (O)

UNIT 1.4

D.C. MOTOR CONTROLS

Variable Voltage Speed Controls

Control by Armature Voltage

D.C. Constant Potential Controls

Principle of Operation
Control Devices and Circuits

Closed-Loop Regulating Systems

Theory of Operation
Methods of Obtaining Feedback Signal
Amplification of Feedback Signal
Error Correction

UNIT 1.5

SINGLE-PHASE CIRCUITS

Alternating Current

Scalar and Vector Quantities
Sine Waves
Phase Relationships
Non-sinusoidal Waveforms
A.C. power: Purely Resistive Circuit

Inductance

Self-inductance
Current in Circuits containing Pure Inductance Only
Current in L-R Circuits
Inductive Reactance
Power Factor
Low Frequency Inductors
Series and Parallel Connections
Impedance

Capacitance

Elementary Capacitor
Construction and Characteristics of Commercial Capacitors
Series and Parallel Connections
Time Constant
Capacitive Reactance
Impedance of a C-R Circuit

Series and Parallel Circuits

L-C-R Series Circuit
Series Resonance
L-C-R Parallel Circuit
Parallel Resonance
Power in L-C-R Circuits

UNIT 1.6

THREE-PHASE CIRCUITS

Three-phase Fundamentals

Three-phase Waveforms
Star and Delta Connections
Three-phase Power

Polyphase Power Rectification

Three-phase Rectifier Systems
Six-phase Rectifier Systems (O)

UNIT 1.7

A.C. MACHINES

Iron-Core Transformers

Mutual Induction
Construction and Function of Parts
Turn and Voltage Ratios
Operation under load
Current Ratios
Vector Diagram Analysis (O)
Losses
Efficiency and Ratings
Single-phase Connections
Auto-transformers
Instrument Transformers (O)
Polyphase Connections
Open-delta (O)

Alternators

Single-phase Alternators—Construction and Operation
Three-phase Alternators—Parts and Construction
Three-phase Connections
Losses, Temperature Rise (O)
Efficiency, Ratings (O)
Voltage Regulation (O)
Synchronization

Three-phase Induction Motors

Principle of Operation
Construction of Squirrel-Cage Induction Motor
Operating Characteristics of Squirrel-Cage Motors
Factors Affecting Speed and Regulation
Wound-Rotor Motor

Single-phase Motors

Survey of Single-phase Motors
Series
Split-phase and Capacitor-start Induction Motors
Shaded Pole
Repulsion-induction (O)

Synchronous Motors (O)

Construction
Principle of Operation
Operating Characteristics

DIVISION 2: ELECTRONICS

INTRODUCTION

The material in Division 2 falls into two classifications: recommended and optional. The recommended portions are considered of a nature fundamental to the teaching of any course in electronics while the optional items indicate possible directions which a class or student might pursue.

Note that the material is in no way an outline of a course of study ready to be used by the teacher. It has intentionally been compiled in a manner which groups topics by generic type without regard to sequence of teaching. With this in mind the units have been assembled, each comprising sections and topics of a similar type, such as standard electronic components, and electron devices. This method provides a satisfactory overview and allows for a simple method of defining of subject depth. At the same time, being open-ended, each unit can sustain additions or deletions from time to time without the overall logical structure being affected. Within this framework the teacher's traditional freedom to plan his own course of study is not impaired: the onus is on him to select material, organize the sequence, and plan lessons and projects.

There has been some criticism in the past about "communications-oriented" courses of study. As a result there has been a conscious effort on the part of the committee to provide a wide enough choice in the optional areas that a teacher can, if he so desires, largely avoid the communications field.

At the same time the committee felt strongly that our task is to teach the fundamentals of electronics and that the areas of "specialization" such as "industrial electronics", "data processing electronics" are simply descriptions of the fields from which meaningful applications of these fundamentals can be drawn. This raises the question of interest and motivation and here a strong argument in favour of the so-called communications field appears. The average student is familiar with and interested in such items as television, high fidelity, guitar amplifiers, portable and car radios; this familiarity makes applications of fundamentals in these areas meaningful. This is not to suggest that process control applications or a data handling are unsuitable or undesirable topics; however, the teacher must overcome the lack of the pre-conditioning motivation that exists in the communications field.

Although vacuum and gaseous tubes are included in this division, the time allotted to these areas should be less than that devoted to semiconductors. With the advent of integrated circuits and computers, students should be given the opportunity to think in terms of electronic systems, and come to appreciate a "systems approach" analysis.

UNIT 2.1

STANDARD ELECTRONIC COMPONENTS

Magnetic Relays

Electromechanical Features
Commercial Types
Typical Applications

Resistors

Types, Applications

Inductors

Types, Applications

Capacitors

Types, Applications

Transformers (Electronic Components)

Iron-core
Air-core
Ferrite-core

UNIT 2.2

ELECTRON DEVICES

Vacuum and Gaseous Tubes

Vacuum Diodes
Vacuum Triodes
Vacuum Pentodes
Multi-purpose Vacuum Tubes
Light-sensitive Tubes
Cathode Ray Tube
Radiation Detectors (O)
Readout Devices (O)

Semiconductors

Basic Physics of Semiconductor Materials
Diodes
Transistors
Other Non-linear Devices (O)

UNIT 2.3

BASIC ELECTRONIC CIRCUITS

Circuits Using Diodes

Power Supplies
Clippers, Clamps and Limiters (O)
Voltage Regulation
Demodulating Circuits

Circuits Using Amplifying Devices

Vacuum tube voltage amplifiers
Vacuum tube power amplifiers
Solid state amplifiers
R.F. amplifiers
Oscillators
S.C.R. circuits
Pulse circuitry (O)
Logic circuits (O)

UNIT 2.4

ELECTRONIC SYSTEMS

NOTE: Select any 3 sections

Audio Amplifiers

Electrical transducer
Audio amplification
High fidelity

Industrial Control

Photoelectric control
Motor control
Regulation: generator voltage and current
Welding control (O)
R.F. heating control (O)

Radio Transmitters and Receivers

Amplitude modulation
Frequency modulation

Digital Computers

Binary notation
Digital electronic systems
Block diagram of basic computer

Television

TV receivers: block diagram
TV systems: closed circuit, broadcast

UNIT 2.5

TEST EQUIPMENT

Conventional Meters (as used in Electronics)

D.C. meters
A.C. meters
The V.O.M.

The Electronic Voltmeter

Voltmeter Function
Ohmmeter Function

The Cathode Ray Oscilloscope

Theory of Operation
Applications
Adjustment and Use

Signal Generators

Audio Frequency
Radio Frequency
Other Types (O)

Utilization of Test Equipment

Exercise of Proper Care
Selection for Specific Use

UNIT 2.6

SERVICING AND TEST PROCEDURES

Identifying the Fault

Symptoms
Intermittents
Analysis of Symptoms

Isolating the Defective Stage

Signal Substitution Method
Bracketing Method
Measurement

Isolating the Defective Component

Observation
Testing Components
Measurement of V, R and I

Repair of the Fault

Component Substitution
Selection Replacement
Installation of Replacement

Complex Systems

Isolation of Defective Section
Isolation of Defective Stage

Routine Maintenance

Reasons for Routine Maintenance
Methods of Preventive Maintenance

Alignment and Calibration

Necessity of Alignment and Calibration of Instrument
Alignment and Calibration Procedure

UNIT 2.7

CONSTRUCTION METHODS AND TECHNIQUES

Development Methods Using Conventional Techniques

Breadboard Construction
Metal Chassis Working
Placement of Components
Wiring Methods

Printed or Etched Wiring

Copper Clad Board
Plain Board

Modular Circuits

Turrets (O)
Packaged Circuits
Plug-in Circuit Boards

Miniaturization

Discrete Components
Thin Film Techniques
Integrated Circuits

DIVISION 3: INSTALLATION AND MAINTENANCE

INTRODUCTION

In many schools this division of Elements of Electrical Technology will be taught in the same room as Division 1. In such cases, one teacher may teach both divisions and the correlation of the material will blend automatically; however, where separate areas exist for Theory and Test, and Installation and Maintenance it is imperative that topic sequence be established by the participating teachers.

This division is very practical in nature, approximately sixty-five per cent of the class time being devoted to student activity. The teacher may increase this ratio through original and imaginative use of available hardware. Every opportunity should be given the students to develop their own circuitry as solutions to various given problems.

Since some of the material may be difficult to present within the electrical shop, field trips are recommended. In this way the student may become familiar with various installation techniques and practices.

In all projects the circuitry and installation procedures should adhere strictly to the Ontario Electrical Code Regulations. These regulations play a substantial role in installation and maintenance, their interpretation and application presenting a challenge to the student. It is recommended, therefore, that open book examinations be used as a means of testing the student's ability to locate and interpret relevant portions of the code.

Throughout the course the instructors should introduce electrical drafting exercises which integrate with the regular course material. The drafting projects should conform to good design practice.

UNIT 3.1

TRADE REQUIREMENTS

Apprenticeship

Educational Requirements
Apprenticeship Act

Social Structure of the Trade

Labour Orangization
Organizational Pattern
Working Conditions

External Jurisdication

Licensing - Municipal, Provincial
Inspection - Municipal, Provincial

UNIT 3.2

ONTARIO ELECTRICAL CODE

Content and Use

Object and Scope
Safety
Approval Procedures
Legal Status
Utilization

UNIT 3.3

ELECTRICAL WIRING SYSTEMS

Non-metallic Sheathed Cable

Regulations
Installation Procedures

Armoured and Aluminum-sheathed Cable

Regulations
Installation Procedures
Testing Armoured Cable
Aluminum-sheathed Cable

Electric Metallic Tubing

Regulations
E.M.T. Fittings
E.M.T. Installation

Rigid Conduit

Regulations
Preparation
Installation

Special Raceway Systems (O)

Types: Surface, Underfloor
Installation Procedures

Signal

Intercommunication System

UNIT 3.4

DISTRIBUTION SYSTEMS

Single Occupancy Services

Regulations
Single-phase, Three-wire System
Service Calculations
Service Materials
Grounding
Service Installation

Multi-occupancy Services

Regulations
Layouts
Service Entrance Materials
Installation

Three-phase Services
Types
Regulations
Metering
Calculations and Materials
Installation

Transformer Installations
Categories
Parts, Nomenclature, and Identification
Name-plate Information
Transformer Bank Connection

Transformer Protection (O)
Primary and Secondary Fusing
High-voltage Protection
Lightning Protection

Transformer Testing and Maintenance (O)
Inspection Prior to Installation
Fluid Maintenance
Leaks
Moisture Removal

UNIT 3.5

A.C. MOTOR CONTROLS

Elements of a Motor Control System
Regulations and Definitions
Disconnecting Means
Overcurrent Protection
Contactor
Overload Protection
Considerations in the Choice of Control System
Combination Starter

Conductors and Protective Devices
Regulations
Fuses vs. Time Delay Fuses
Circuit Breakers: Types and Sizes
Calculations for Motor Grouping

Manual Starting Switches
Single-phase, Across-the-line Motor Starting Switches
Single-phase Reversing Drum Controllers
Three-phase Drum Reversing Controllers

Magnetic Across-the-Line Starters
Internal Circuit
Related Control Devices
Reversing Magnetic Starters

Reduced-Voltage Starters
Purpose
Features
Automatic Compensator
Wye-delta Starters

UNIT 3.6

ELECTRICAL MAINTENANCE

Diagnosis of Faulty Circuits
Circuit Analysis and Tests
Test Equipment Requirements

Industrial Equipment
Controls
Motors
Preventive Maintenance

Domestic Appliances
Any two of:
Water Heaters
Ranges
Dryers
Oil Burners

LABORATORY SKILLS AND TECHNIQUES

The graduate of Elements of Electrical Technology should be able to perform laboratory experiments accurately and report them clearly.

Before the student reaches this stage, however, he will need careful and explicit instruction in the experimental method. He will need to watch demonstrations of relevant procedures and skills and he should study examples of good report writing and organization.

An important part of the Elements of Electrical Technology course is the preparation of technical articles. The student will probably consult the teacher before choosing his topics, but from that point on he will work independently, do individual research, and supply at least three or four reference sources. This is a good time for the teacher to emphasize the importance of language skills in technical subjects: he may ask a member of the English Department to judge the composition of the essays, with emphasis on clarity rather than style.

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ELEMENTS OF ELECTRICAL TECHNOLOGY

CURRICULUM GUIDE
SUPPLEMENT TO S27B

ONTARIO DEPARTMENT OF EDUCATION

1969
SENIOR DIVISION

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USE OF THE CURRICULUM GUIDE

This publication is a teachers' guide that expands Elements of Electrical Technology, Curriculum S-27B. Teachers may use the additional material to whatever degree they wish: they should not consider the Guide as mandatory subject content.

All Divisions, Units, Sections, and Topics are identical to those that appear in Curriculum S-27B. Note that (O) indicates optional material. The Elements column continues the analytical breakdown beyond the Topics level. It completes the exploded-view concept in which each Division is analyzed in a series of five steps, each step representing a dissection of the former. Thus, Section content is made explicit by its associated Topics and each Topic is made explicit by its associated Elements.

A numbering system is used to designate each subdivision of the course. It is organized in such a way that, reading from left to right:

- The first number indicates the Division
- The second number indicates the Unit
- The third number indicates the Section
- The fourth number indicates the Topic
- The fifth number indicates the Element

As an example of this arrangement, 1125.1 refers to Division 1, Unit 1, Section 2, Topic 5, and Element 1. The number of digits denotes the degree of breakdown: as a case in point, 32.1 indicates Section 1, Unit 2 of Division 3.

Although each Unit, Section, and Topic is developed in a logical manner, **no attempt has been made to divide the course into "lessons" nor does the Guide provide the teacher with a chronological sequence.** Since the complete two-year course is treated as an entity, the arrangement of subject material into weekly, monthly, and yearly sequences is the task of the teachers. They must shape the subject content into a cohesive pattern in which relationships and principles are stressed.

The Cross-Reference column utilizes the numbering system to facilitate integration of the course as a whole. Many, but by no means all of the possible cross-references have been listed. Undoubtedly the teacher will add or delete according to his own perspective. The numbers do not necessarily correspond to the element which appears in the same horizontal line: rather, the numbers relate to the topic with which they are associated. No precise alignment was possible.

The Fundamentals column contains the basic concepts and principles which make the study of electricity and electronics a formative educational experience. This column is an attempt to generalize from the particular Section, Topic, and Element material; it is **not** a further breakdown of the Elements. Concepts, principles, laws, and rules are included, along with the relevant mathematical expressions. Obviously, if a student gains a clear grasp of these fundamentals, he will possess a sound foundation for study in electrical technology.

In Division 3 the Fundamentals column has been replaced by one headed Regulations. Since this Division mainly deals with electrical installations, references to the electrical codes are particularly relevant. The theoretical aspects of the hardware referred to in Division 3 are studied in Division 1, as indicated by the cross-references.

The concepts that have a (C) after them are those which have broad applications in several disciplines or fields. For example, "feedback" occurs in a wide range of physical and social contexts.

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In Division 3 the Fundamentals column has been replaced by one headed Regulations. Since this Division mainly deals with electrical installations, references to the electrical codes are particularly relevant. The theoretical aspects of the hardware referred to in Division 3 are studied in Division 1, as indicated by the cross-references. The concepts that have a (C) after them are those which have broad applications in several disciplines or fields. For example, "feedback" occurs in a wide range of physical and social contexts.

The Technical Terms column consists of a list of those technical terms that the students must understand in order to grasp the topic under consideration. Many of these items need to be formally defined: others may only require familiarity on the part of the student.

Student activities of several kinds are suggested. These refer to those activities which the student performs without direct supervision and frequently include the use of hardware. The letter (E) after the title indicates an experiment which is to be done; the letter (X) denotes problem-solving periods devoted to calculations done on paper; the letter (A) refers to an application study in which the student is directed to scrutinize an industrial application or applications, particularly as to design features; the letter (P) designates a project of some kind. Teachers should encourage their students to embark upon major projects which involve knowledge from several Divisions: such projects provide a valuable integrating experience and relate to real-life situations more closely than isolated experiments.

Note that student activity should exceed fifty per cent of the time available. Learning situations in which the individualized, inductive approach is possible should increase this ratio considerably. Whatever the methods, student comprehension is the main aim rather than completion of course content.

The Discussion column is an attempt to communicate relevant information or ideas not conveyed elsewhere. Items are clarified or amplified and some suggestions as to method are proposed.

COURSE IMPLEMENTATION	POSSIBLE COURSE DESIGNATIONS	CONTENT	APPROXIMATE DURATION		TEACHER REQUIREMENTS	
			YEARS	HOURS		
The complete course as suggested in this Guide can be implemented in approximately 600 hours of student time, spread over a two-year period. This would appear to meet the needs of the committed students who intend to seek employment or advance to a college of applied arts and technology upon graduation. We must, however, adjust also to the requirements of other students who may wish a modified program. The chart on this page indicates some of the possible courses which can be drawn from Curriculum S-27B and this Guide.	Elements of Electrical Technology 1	Divisions 1, 2, & 3	Two	600	Two	An integra wishes to The gradu (probably broad fiel
	Elements of Electrical Technology II	Divisions 1, 2, & 3	Two	300	Two	An integra for univer
	Elements of Electrical Technology III	Divisions 1 & 2	Two	240	One or Two	A truncat omit the though th might ele
	Elements of Electrical Technology IV	Divisions 1 & 3	Two	240	One or Two	A truncat omit the covers tw for one ye
	Electrical Theory & Test I	Division 1	One	120	One	A course foundatio
	Electrical Theory & Test II	Division 1	One Half	60	One	A semeste mentals, difficulty.
	Electronics I	Division 2	One	120	One	A course insight int cation.
	Electronics II	Division 2	One Half	60	One	A semest of electro degree of
	Electrical Installation & Maintenance	Division 3	One Half	60	One	A semest which bas taught.

IBLE COURSE SIGNATIONS	CONTENT	APPROXIMATE DURATION		TEACHER REQUIRE-MENTS	COMMENT
		YEARS	HOURS		
nts of Electrical chnology 1	Divisions 1, 2, & 3	Two	600	Two	An integrated technical course for the student who wishes to major in electrical studies. The graduate might proceed to tertiary education (probably to a C.A.A.T.) or seek employment in the broad field of applied electricity and electronics.
nts of Electrical chnology II	Divisions 1, 2, & 3	Two	300	Two	An integrated technical course primarily intended for university-bound students.
nts of Electrical chnology III	Divisions 1 & 2	Two	240	One or Two	A truncated version which permits the student to omit the installation and maintenance work. Although the course covers two years, the student might elect to take it for one year only.
nts of Electrical chnology IV	Divisions 1 & 3	Two	240	One or Two	A truncated version which permits the student to omit the Electronics Division. Although the course covers two years, a student might elect to take it for one year only.
l Theory & Test I	Division 1	One	120	One	A course for the student who wishes to gain a solid foundation in electrical fundamentals.
l Theory & Test II	Division 1	One Half	60	One	A semestered course, dealing with electrical fundamentals, which might be offered at a high degree of difficulty.
ectronics I	Division 2	One	120	One	A course for the student who wishes to obtain an insight into electronics as part of his general education.
ectronics II	Division 2	One Half	60	One	A semestered course, dealing with basic concepts of electronics, which might be offered at a high degree of difficulty.
cal Installation & aintenance	Division 3	One Half	60	One	A semestered course of a very practical nature in which basic wiring methods and techniques are taught.

DIVISION 1: Theory and Test

UNIT: 1.1 Fundamentals of Electr

Section	Topic	Element
11.1 Direct Current	**111.1 Electron theory**	1111.1 Structure of matter 1111.2 Structure of the atom 1111.3 Atomic particles
	111.2 Electrical charges	1112.1 Nature of an electrical charge 1112.2 Unit of electrical charge 1112.3 Electrostatic fields 1112.4 Behaviour of charged bodies 1112.5 Force between charged bodies
	111.3 Methods of producing EMF	1113.1 Friction 1113.2 Chemical reaction 1113.3 Electromagnetic induction 1113.4 Heat 1113.5 Light 1113.6 Piezoelectric effect
	111.4 Electrical circuits	1114.1 Simple circuits: series, parallel 1114.2 Current, voltage and resistance relationships

UNIT: 1.1 Fundamentals of Electricity and Magnetism

ic	Element	Cross-Reference	Fundamentals
on theory	1111.1 Structure of matter 1111.2 Structure of the atom 1111.3 Atomic particles	1115.1 221.6	Electron theory
ical charges	1112.1 Nature of an electrical charge 1112.2 Unit of electrical charge 1112.3 Electrostatic fields 1112.4 Behaviour of charged bodies 1112.5 Force between charged bodies	153.1 221.1 222.1 221.6	Law of Electrostatic Charges Coulomb's Law $F \propto \frac{q_1 q_2}{d^2}$ Inverse Square Law (C)
ds of cing EMF	1113.1 Friction 1113.2 Chemical reaction 1113.3 Electromagnetic induction 1113.4 Heat 1113.5 Light 1113.6 Piezoelectric effect	132.3 131.1 1.7 2421.6 2224.1 2325.3 2411.3 2411.4	Principle of electromagnetic induction Electrochemical series Conservation of energy
ical circuits	1114.1 Simple circuits: series, parallel 1114.2 Current, voltage and resistance relationships	331.2 152.8 3611.3	Ohm's Law

Technical Terms	Suggestions for Student Activity	Dis
Atom Proton Electron Neutron Electrical charge Ion		The electron theory previously understanding of voltage, curr electron theory is obtained. En studied in an elementary manne
	COULOMB'S LAW (E) • confirm that the force between charged bodies is inversely proportional to the square of the distance.	The electrostatic field between examined.
Electromotive force Electromagnetic induction Electrochemical series Thermocouple Photovoltaic Piezoelectric Fuel cell	**PRODUCING EMF (E)** • study the various methods of producing emf.	The various methods of produ relative importance of each disc
Source Load Control Conduct Open, closed and short circuits Series, parallel circuits	**OHM'S LAW (E)** • plot the volt-ampere curves of linear resistances.	The basic ideas underlying cu should be stressed. Ohm's Law forms of an equation.

Suggestions for Student Activity	Discussion
	The electron theory previously studied should be reviewed so that an understanding of voltage, current and resistance with reference to the electron theory is obtained. Energy levels and electron shells, should be studied in an elementary manner.
LOMB'S LAW (E) nfirm that the force between charged bodies is inversely proonal to the square of the distance.	The electrostatic field between two charged (bodies) plates should be examined.
UCING EMF (E) udy the various methods of producing emf.	The various methods of producing an emf should be demonstrated, the relative importance of each discussed, and their application considered.
'S LAW (E) t the volt-ampere curves of linear resistances.	The basic ideas underlying current, electromotive force and resistance should be stressed. Ohm's Law should not merely be thought of as three forms of an equation.

DIVISION 1: Theory and Test

UNIT: 1.1 Fundamentals of Electri

Section	Topic	Element	Re
11.1 Direct Current (continued)	**111.4 Electrical Circuits (continued)**	1114.3 Series Circuit Characteristics	1
		1114.4 Parallel Circuit Characteristics	1
		1114.5 Series-Parallel Circuit Characteristics	
		1114.6 Internal source resistance	1 1 1 2
	111.5 Electrical Conductors and Insulators	1115.1 Atomic Structure of Common Conductors and Insulators	2
		1115.2 Factors Affecting Resistance: Length, Area, Resistivity, Temperature	22
		1115.3 Physical Properties of Insulating Materials and Conductors	36

Test

UNIT: 1.1 Fundamentals of Electricity and Magnetism

Topic	Element	Cross-Reference	Fundamentals
11.4 Electrical Circuits (continued)	1114.3 Series Circuit Characteristics	152.7	$R = R_1 + R_2 + \dots R_n$ Kirchhoff's Voltage Law, $\sum V = 0$
	1114.4 Parallel Circuit Characteristics	153.3	$R = \dfrac{1}{1/R_1 + 1/R_2 + \dots 1/R_n}$ Kirchhoff's Current Law, $\sum I = 0$
	1114.5 Series-Parallel Circuit Characteristics		
	1114.6 Internal source resistance	1315.1 1315.2 1726.2 2212.1	Internal Resistance (C)
1.5 Electrical Conductors and Insulators	1115.1 Atomic Structure of Common Conductors and Insulators	111.1 222.1	Electron Theory
	1115.2 Factors Affecting Resistance: Length, Area, Resistivity, Temperature	2224.1	$R = \dfrac{KL}{A}$
	1115.3 Physical Properties of Insulating Materials and Conductors	153.1 153.2 121.4 3611.2	

Technical Terms	Suggestions for Student Activity	
Series Circuit Sigma, Algebraic Sum	**SERIES AND PARALLEL CIRCUITS (E)** • verify the E, I and R relationships for the above circuits.	A properly organized metho reviewed and practice given series and in parallel.
Parallel Circuit Branch Reciprocal	**SERIES-PARALLEL CIRCUITS (E)** • determine experimentally the characteristics of series-parallel circuits.	The student should realize t sented by an equivalent seri parallel circuit should be illus
Series-Parallel Circuit	**KIRCHHOFF'S LAWS (E)** • verify Kirchhoff's Laws for current and voltage.	
Terminal, Open-Circuit and Full-Load Voltage Internal Resistance	**INTERNAL RESISTANCE (E)** • determine the internal resistance of an electrical source.	Internal resistance is presen influence on all electrical syst
Conductor Semiconductor Insulator Free, bound electrons Specific resistance Circular mils Positive, negative Temperature coefficients Classes of Insulation	**TEMPERATURE EFFECTS (E)** • demonstrate the effect of temperature on the resistance of tungsten and carbon. **MEASURING CONDUCTOR SIZES (E)** • determine the area of solid and stranded conductors using a micrometer and a wire gauge.	It is important that the differ and insulators be defined. The student should be famili ment, and with wire tables. Superconductivity at low te includes a study of the chara low temperatures.

Suggestions for Student Activity	Discussion
AND PARALLEL CIRCUITS (E) y the E, I and R relationships for the above circuits.	A properly organized method of solving electrical problems should be reviewed and practice given in solving problems involving resistors in series and in parallel.
-PARALLEL CIRCUITS (E) rmine experimentally the characteristics of series-parallel .	The student should realize that the series-parallel circuit may be represented by an equivalent series circuit and the method of solving a series-parallel circuit should be illustrated.
HOFF'S LAWS (E) y Kirchhoff's Laws for current and voltage.	
IAL RESISTANCE (E) rmine the internal resistance of an electrical source.	Internal resistance is present in all devices and exerts a current-limiting influence on all electrical systems.
RATURE EFFECTS (E) onstrate the effect of temperature on the resistance of en and carbon.	It is important that the differences in the atomic structures of conductors and insulators be defined. The student should be familiar with the circular mil as a unit of measurement, and with wire tables.
RING CONDUCTOR SIZES (E) rmine the area of solid and stranded conductors using a eter and a wire gauge.	Superconductivity at low temperature is an interesting study. This topic includes a study of the characteristics of insulating materials at high and low temperatures.

Section	Topic	Element	Cross-Reference
11.1 Direct Current (continued)	**111.6 Electrical Power and Energy**	1116.1 Definition of Work, Energy, and Power	
		1116.2 Relationship between Mechanical and Electrical Energy and Power	2411.1 13.1 13.2 17.3 17.2
		1116.3 Measurement of Electrical Power and Energy	151.5 152.5 154.5 161.3
		1116.4 Power Rating of Electrical Equipment	
11.2 Magnetism	**112.1 Theory of Magnetism**	1121.1 Relationship of Magnetism to Motion of Electrons	
		1121.2 Arrangement of Atoms in Domains	
		1121.3 Magnetic Poles	
	112.2 Magnetic Fields	1122.1 Properties of magnetic lines	12.1 1.3 1.7
		1122.2 Law of Magnetic Poles	
	112.3 Magnetic Properties of Materials	1123.1 Types: Magnetic, Nonmagnetic	1.3
		1123.2 Permeability of Materials	
		1123.3 Magnetic Saturation and B-H Curves	131.4
		1123.4 Hysteresis Loops	

UNIT: 1.1 Fundamentals of Electricity and Magnetism

Topic	Element	Cross-Reference	Fundamentals
Electrical Power and Energy	1116.1 Definition of Work, Energy, and Power		Energy Power $W = Fd; P = \frac{W}{t}$
	1116.2 Relationship between Mechanical and Electrical Energy and Power	2411.1 13.1 13.2 17.3 17.2	Energy conversion 1 H.P. = 746 watts
	1116.3 Measurement of Electrical Power and Energy	151.5 152.5 154.5 161.3	$P = E I$ $\text{Energy} = P \times t$
	1116.4 Power Rating of Electrical Equipment		
Theory of Magnetism	1121.1 Relationship of Magnetism to Motion of Electrons		Fields of Force (C)
	1121.2 Arrangement of Atoms in Domains		Domain Theory of Magnetism
	1121.3 Magnetic Poles		
Magnetic Fields	1122.1 Properties of magnetic lines	12.1 1.3 1.7	Properties of Magnetic Lines
	1122.2 Law of Magnetic Poles		Law of Magnetic Poles
Magnetic Properties of Materials	1123.1 Types: Magnetic, Nonmagnetic	1.3	
	1123.2 Permeability of Materials		
	1123.3 Magnetic Saturation and B-H Curves	131.4	Saturation (C) $\mu = B/H$
	1123.4 Hysteresis Loops		Hysteresis

Technical Terms	Suggestions for Student Activity	Dis
Work, Energy, Power Horsepower Watt, Kilowatt Joule, Watt-Second Kilowatt-Hour	**D.C. POWER (E)** • measure electrical power by the voltmeter-ammeter and wattmeter methods simultaneously. **ENERGY CALCULATION (P)** • Calculation of an energy bill. **POWER RATINGS (E)** • check the power rating of devices at their rated voltage. • determine the effect of voltage variations on power of a device.	The limiting effect of heat on appreciated.
Magnetic Lines; Magnetic Field, Flux Domains Induced Magnetism		Films are a good source of up-to-
Magnetic Poles, Polarity		
Magnetic, Nonmagnetic Permeability Magnetic Saturation Flux Density (B) Magnetizing Force (H) Hysteresis	**PERMEABILITY CURVES** • plot permeability curves for commercial magnetic materials using manufacturer's B-H data.	The relationship between permea may be effectively shown by mean Hysteresis loops for various com the relationship between the sha the hysteresis loss discussed.

Suggestions for Student Activity	Discussion
R (E) electrical power by the voltmeter-ammeter and watt-ods simultaneously. **ALCULATION (P)** on of an energy bill. **TINGS (E)** power rating of devices at their rated voltage. e the effect of voltage variations on power of a device.	The limiting effect of heat on the power rating of devices should be appreciated.
	Films are a good source of up-to-date information on this topic.
TY CURVES eability curves for commercial magnetic materials acturer's B-H data.	The relationship between permeability and flux density should be noted and may be effectively shown by means of a graph. Hysteresis loops for various commercial materials should be studied and the relationship between the shape of the hysteresis loop and the value of the hysteresis loss discussed.

Section	Topic	Element
11.2 Magnetism (continued)	**112.4 Electromagnetism**	1124.1 Magnetic Field about a Current-Carrying Conductor; Hand Rule 1124.2 Magnetic Field about a Current-Carrying Coil; Hand Rule 1124.3 Factors affecting Strength of an Electromagnet
	112.5 Magnetic Circuits	1125.1 Relationship among Flux, Magnetizing Force and Reluctance 1125.2 Magnetic Units 1125.3 Series Magnetic Circuit Without Air Gap 1125.4 Series Magnetic Circuit With Air Gap

UNIT: 1.1 Fundamentals of Electricity and Magnetism

Topic	Element	Cross-Reference	Fundamentals
112.4 Electromagnetism	1124.1 Magnetic Field about a Current-Carrying Conductor; Hand Rule	21.1 21.3	Current-Magnetic Field Relationship
	1124.2 Magnetic Field about a Current-Carrying Coil; Hand Rule	122.4 122.3 15.2	
	1124.3 Factors affecting Strength of an Electromagnet		
112.5 Magnetic Circuits	1125.1 Relationship among Flux, Magnetizing Force and Reluctance	3541.2	Magnetic Circuit Law $\phi \propto \frac{F}{R}$
	1125.2 Magnetic Units	1.3 1.7	
	1125.3 Series Magnetic Circuit Without Air Gap		
	1125.4 Series Magnetic Circuit With Air Gap		

Technical Terms	Suggestions for Student Activity	Dis
Solenoid Hand Rules	**MAGNETIC POLE WINDINGS (E)** • connect the pole windings of a generator to specified polarity. **FACTORS AFFECTING STRENGTH OF ELECTROMAGNETS** • study the factors affecting the strength of electromagnets.	Teachers should develop or adap ship which exists between ampe A flux meter would be useful fo
Magnetomotive Force Magnetic Units Reluctance	**EFFECT OF AIR GAP ON A SERIES MAGNETIC CIRCUIT (F)** • study the effect of an air gap on the flux in a series magnetic circuit. A flux meter could be used to indicate relative amount of flux change. **RELAYS (A)** • study the operation of various relays.	Reference should be made to t encountered in motors, relay reactors.

Suggestions for Student Activity	Discussion
NETIC POLE WINDINGS (E) nect the pole windings of a generator to specified polarity. **ORS AFFECTING STRENGTH OF ELECTROMAGNETS** dy the factors affecting the strength of electromagnets.	Teachers should develop or adapt some equipment to illustrate the relationship which exists between ampere-turns, flux and reluctance. A flux meter would be useful for experimental work in this section.
T OF AIR GAP ON A SERIES MAGNETIC CIRCUIT (F) dy the effect of an air gap on the flux in a series magnetic t. A flux meter could be used to indicate relative amount of hange. **YS (A)** dy the operation of various relays.	Reference should be made to the various magnetic circuits that will be encountered in motors, relays, meters, transformers, and saturable reactors.

DIVISION 1: Theory and Test
(continued)

UNIT: 1.2 Electrica

Section	Topic	Element	Cross Referen
12.1 D.C. instruments	**121.1 D'Arsonval Movement**	1211.1 Basic Structure 1211.2 Production of Torque 1211.3 Construction of Practical Instrument 1211.4 Damping 1211.5 Galvanometer 1211.6 Application as an Ammeter 1211.7 Instrument Polarity 1211.8 Meter Sensitivity 1211.9 Shunts 1211.10 Application as a Voltmeter 1211.11 Multipliers 1211.12 Ohms per volt rating	11.2 132.1 132.6 1113.3 3612.4 2511.1 122.1 122.2
	121.2 Instrument Reading	1212.1 Interpreting the Scale 1212.2 Zero Adjustment 1212.3 Avoidance of Parallax 1212.4 Physical Position	25.1 361.2
	121.3 Series ohmmeter	1213.1 Principle of Operation 1213.2 Multirange Ohmmeters 1213.3 Precautions for use	1114.2
	121.4 Insulation Tester	1214.1 Operation of "Megger" Circuit 1214.2 Precautions in use	3612.2 1115.3

Test
d)

UNIT: 1.2 Electrical Measurement

Topic	Element	Cross-Reference	Fundamentals
21.1 D'Arsonval Movement	1211.1 Basic Structure	11.2	Motor Principle Torque $\propto \phi I$ Damping (C) Polarity (C) Ohm's Law Linearity
	1211.2 Production of Torque	132.1	
	1211.3 Construction of Practical Instrument	132.6	
	1211.4 Damping	1113.3	
	1211.5 Galvanometer		
	1211.6 Application as an Ammeter	3612.4	
	1211.7 Instrument Polarity		
	1211.8 Meter Sensitivity	2511.1	
	1211.9 Shunts	122.1	
	1211.10 Application as a Voltmeter	122.2	
	1211.11 Multipliers		
	1211.12 Ohms per volt rating		
21.2 Instrument Reading	1212.1 Interpreting the Scale		Measurement (C) Accuracy
	1212.2 Zero Adjustment	25.1	
	1212.3 Avoidance of Parallax	361.2	
	1212.4 Physical Position		
21.3 Series ohmmeter	1213.1 Principle of Operation		Ohmmeter principle Nonlinearity
	1213.2 Multirange Ohmmeters	1114.2	
	1213.3 Precautions for use		
21.4 Insulation Tester	1214.1 Operation of "Megger" Circuit	3612.2 1115.3	Leakage current
	1214.2 Precautions in use		

Technical Terms	Suggestions for Student Activity	
Torque Damping Galvanometer Ammeter Voltmeter Polarity Shunts Multipliers Meter Sensitivity Range Hairsprings Jewel bearings Linear scale	**THE D'ARSONVAL GALVANOMETER (E)** • study the operating principle of the D'Arsonval Galvanometer. **THE D.C. AMMETER (E)** • calculate the resistance of the shunt required for a milliammeter to construct an ammeter of a given range. • Use shunts and a milliammeter to construct ammeters of various ranges. Check the accuracy of each ammeter constructed. **THE D.C. VOLTMETER (E)** • calculate the value of the series resistor required for a millivoltmeter of a given range. • Construct the voltmeter and check its accuracy.	The pupils should have a instruments so that their Proper instrument selec cussed and practiced thro Problems should be assi shunts, series resistance
Interpolation Parallax		The possible accuracy o should be discussed. Co
Ohmmeter Infinity Nonlinear scale Half-scale resistance	**SERIES OHMMETER (E)** • became familiar with the use of the ohmmeter and its principle of operation.	A discussion of the fact helps pupils understand t
Megohm Current coil Potential coil	**INSULATION MEASUREMENT (E)** • use a "megger" to measure the insulation resistance of motors, generators and circuits.	A detailed study of the "

ggestions for Student Activity	Discussion
NVAL GALVANOMETER (E) perating principle of the D'Arsonval Galvanometer.	The pupils should have an appreciation of the construction features of D.C. instruments so that their capabilities and limitations may be understood.
METER (E) e resistance of the shunt required for a milliammeter n ammeter of a given range. s and a milliammeter to construct ammeters of s. Check the accuracy of each ammeter constructed.	
LTMETER (E) e value of the series resistor required for a milli- given range. he voltmeter and check its accuracy.	Proper instrument selection for accurate measurements should be discussed and practiced throughout the course.
	Problems should be assigned for practice in calculating the resistance of shunts, series resistances and multipliers.
	The possible accuracy of the readings obtained when using instruments should be discussed. Consider instrument and human errors.
METER (E) iliar with the use of the ohmmeter and its principle	A discussion of the factors affecting the accuracy of ohmmeter readings helps pupils understand the limitations of the instrument.
MEASUREMENT (E) ger" to measure the insulation resistance of motors, circuits.	A detailed study of the "megger" is not required.

UNIT: 1.2 Electrical

Section	Topic	Element	Cross- Referenc
12.2 A.C. Instruments	**122.1 Rectifier Instruments**	1221.1 Principle of operation	121.1
		1221.2 Current Measurement	
		1221.3 Voltage Measurement	251.2
		1221.4 Advantages and disadvantages compared to other A.C. instruments	
	122.2 Multimeters	1222.1 Use of One Movement for Several Functions	3612.4 251.3
		1222.2 Typical Circuit	
		1222.3 Precautions for Use	
	122.3 Moving Iron Instruments (O)	1223.1 Principle of Operation	1122.2
		1223.2 Construction of Vane Types	
		1223.3 Limitations	
		1223.4 Applications	
	122.4 Electro-dynamometer (O)	1224.1 Principle of operation	112.4
		1224.2 Construction	1525.3
		1224.3 Power Measurement and Other Applications	3612.6 1613.2
12.3 Electrical Bridges	**123.1 The Wheatstone bridge**	1231.1 Circuit Configuration	2521.3
		1231.2 Arm Ratios	
		1231.3 Conditions for Balance	2311.4
		1231.4 Precision Capabilities	
		1231.5 Application	
	123.2 Introduction to A.C. bridges	1232.1 Use of Capacitance Bridge	
		1232.2 Use of Inductance Bridge	
		1232.3 Use of Impedance Bridge	

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Test

UNIT: 1.2 Electrical Measurement

Topic	Element	Cross-Reference	Fundamentals
122.1 Rectifier Instruments	1221.1 Principle of operation 1221.2 Current Measurement 1221.3 Voltage Measurement 1221.4 Advantages and disadvantages compared to other A.C. instruments	121.1 251.2	Rectification
122.2 Multimeters	1222.1 Use of One Movement for Several Functions 1222.2 Typical Circuit 1222.3 Precautions for Use	3612.4 251.3	Range
122.3 Moving Iron Instruments (O)	1223.1 Principle of Operation 1223.2 Construction of Vane Types 1223.3 Limitations 1223.4 Applications	1122.2	Magnetic Repulsion Magnetic Induction
122.4 Electro-dynamometer (O)	1224.1 Principle of operation 1224.2 Construction 1224.3 Power Measurement and Other Applications	112.4 1525.3 3612.6 1613.2	Magnetic Field Interaction
123.1 The Wheatstone bridge	1231.1 Circuit Configuration 1231.2 Arm Ratios 1231.3 Conditions for Balance 1231.4 Precision Capabilities 1231.5 Application	2521.3 2311.4	$Rx = \frac{R_1 \cdot R_3}{R_2}$
123.2 Introduction to A.C. bridges	1232.1 Use of Capacitance Bridge 1232.2 Use of Inductance Bridge 1232.3 Use of Impedance Bridge		

Technical Terms	Suggestions for Student Activity	Discus
Rectifier Moving-coil instrument Bridge connection Half-wave Full-wave Rms value Average value Pulsating current Uni-directional current	**THE RECTIFIER TYPE A.C. VOLTMETER (E)** • become familiar with the circuit of the rectifier type instrument and its application.	Application of rectifier type of inst scales.
Multimeter Function Switch, Range Switch	**MULTIMETER (E)** • become familiar with the use of a multimeter, by measuring voltage, current and resistance.	Pupils should be aware of the ad amplifier and non-amplifier types of m
Iron Vane Meter	**IRON VANE METER (E)** • study the principle of the iron vane meter and its application in A.C. ammeters and voltmeters.	The advantages, disadvantages (limi ent types of A.C. instruments should
Electrodynamometer Wattmeter	**ELECTRODYNAMOMETER (E)** • study the electrodynamometer principle and its application in measuring instruments.	
Electrical Bridge Balanced Conditions, Null	**WHEATSTONE BRIDGE (E)** • become familiar with the operation of a Wheatstone bridge by measuring high and low resistances.	Practice should be given in the s resistance value using bridge princip
Capacitance Bridge Inductance Bridge Impedance Bridge	**IMPEDANCE BRIDGE (E) (O)** • become familiar with the operation of an Impedance bridge by measuring values of R, L and C.	Basic comparison of D.C. and A.C. bri

Suggestions for Student Activity	Discussion
E RECTIFIER TYPE A.C. VOLTMETER (E) ecome familiar with the circuit of the rectifier type instrument its application.	Application of rectifier type of instruments and characteristics of their scales.
LTIMETER (E) ecome familiar with the use of a multimeter, by measuring tage, current and resistance.	Pupils should be aware of the advantages and disadvantages of the amplifier and non-amplifier types of multimeters.
N VANE METER (E) tudy the principle of the iron vane meter and its application in . ammeters and voltmeters.	The advantages, disadvantages (limitations) and applications of the different types of A.C. instruments should be considered.
CTRODYNAMOMETER (E) tudy the electrodynamometer principle and its application in asuring instruments.	
EATSTONE BRIDGE (E) ecome familiar with the operation of a Wheatstone bridge by asuring high and low resistances.	Practice should be given in the solution of problems on determining resistance value using bridge principle.
PEDANCE BRIDGE (E) (O) ecome familiar with the operation of an Impedance bridge by asuring values of R, L and C.	Basic comparison of D.C. and A.C. bridges is recommended.

DIVISION 1: Theory and Test

UNIT: 1.

Section	Topic	Element	Cros Refere
13.1 D.C. generator	**131.1 Electromagnetic Induction**	1311.1 Faraday's Law 1311.2 Relationship among Magnetic Field, Motion of Conductor and direction of the induced emf	1113.3
	131.2 Single Loop Generator	1312.1 Alternating Voltage Generation 1312.2 Instantaneous Values 1312.3 Sinusoidal Waveforms 1312.4 Simple Commutation	151.2 172.1 2325.2 1512.4
	131.3 Construction and internal connections	1313.1 Parts and their Functions 1313.2 Series, Shunt and Compound Generators 1313.3 Multipole Generators	17.2
	131.4 Self-excitation	1314.1 Generator Saturation Curve 1314.2 Field Resistance Lines 1314.3 Voltage Build-Up to Stable Operating Point 1314.4 Voltage Control by Field Rheostat	1123.4 1123.3 1114.2 2121.2
	131.5 Operating Characteristics	1315.1 Variation of Terminal Voltage for each type under varying load 1315.2 Voltage Regulation 1315.3 Effects of Armature Reaction	1114.6 1714.3 231.1 172.6
	131.6 Commutation	1316.1 Ideal Commutation 1316.2 Armature Reaction and its Effect upon Commutation 1316.3 Methods of Compensating for Armature Reaction 1316.4 Emf of Self-induction	1324.3

UNIT: 1.3 D.C. Machines

Topic	Element	Cross-Reference	Fundamentals
Electromagnetic Induction	1311.1 Faraday's Law	1113.3	Principle of electromagnetic induction
	1311.2 Relationship among Magnetic Field, Motion of Conductor and direction of the induced emf		Faraday's Law: $E_{av} \propto \frac{\phi_1 - \phi_2}{t}$ Fleming's hand rule
Single Loop Generator	1312.1 Alternating Voltage Generation		Bidirectional Flow (C)
	1312.2 Instantaneous Values	151.2	
	1312.3 Sinusoidal Waveforms	172.1	
	1312.4 Simple Commutation	2325.2 1512.4	Rectification (C)
Construction and internal connections	1313.1 Parts and their Functions	17.2	
	1313.2 Series, Shunt and Compound Generators		
	1313.3 Multipole Generators		
Self-excitation	1314.1 Generator Saturation Curve		Saturation (C)
	1314.2 Field Resistance Lines	1123.4	Linearity (C)
	1314.3 Voltage Build-Up to Stable Operating Point	1123.3	Stability (C)
	1314.4 Voltage Control by Field Rheostat	1114.2 2121.2	Ohm's Law
Operating Characteristics	1315.1 Variation of Terminal Voltage for each type under varying load	1114.6 1714.3	Regulation (C) % voltage regulation
	1315.2 Voltage Regulation	231.1	$= \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100$
	1315.3 Effects of Armature Reaction	172.6	
Commutation	1316.1 Ideal Commutation		
	1316.2 Armature Reaction and its Effect upon Commutation	1324.3	
	1316.3 Methods of Compensating for Armature Reaction		Rectification (C)
	1316.4 Emf of Self-induction		Self-induction

Technical Terms	Suggestions for Student Activity	Di
Electromagnetic induction Induced emf	**ELECTROMAGNETIC INDUCTION** • demonstrate Faraday's Law by moving a conductor through a magnetic field and by changing the flux linked by the coil.	The application of the principle tion of generators, motors, tran
Instantaneous value Sinusoidal waveform Commutator Commutation Mechanical rectifier	**SINGLE LOOP GENERATOR (E)** • use a single loop generator to illustrate electromagnetic induction.	In addition to pointing out that a is a relative motion of the con emphasized that an emf is ind changes.
Armature, series and shunt field coils Series, shunt and compound generators Multipole Commutator, brushes	**GENERATOR TYPES AND CONNECTION (E)** • study the connections of shunt, series and compound generators, make connections and check for build-up.	The potentials developed in th (A.C. and D.C.) are alternating
Magnetic Saturation Field Resistance Line Voltage "Build-Up" Rheostat	**SATURATION CURVE (E)** • determine the saturation curve of a D.C. generator. **GENERATOR SELF-EXCITATION (E)** • study the manner in which a self-excited generator builds up to stable terminal voltage.	Reasons for failure to build up
Cumulative connection Differential connection Voltage Regulation Armature Reaction	**LOAD CHARACTERISTIC CURVES (E)** • determine the operating characteristics of various types of D.C. generators.	The voltage characteristic curv should be discussed.
Commutation Neutral plane Emf of self-induction Interpoles	**COMMUTATION (E)** • study the various methods of improving commutation and show experimentally commutation improvement by brush shifting and by use of interpoles.	Reasons for brush sparking a sidered.

Suggestions for Student Activity	Discussion
ROMAGNETIC INDUCTION onstrate Faraday's Law by moving a conductor through a tic field and by changing the flux linked by the coil.	The application of the principle of electromagnetic induction in the operation of generators, motors, transformers and chokes should be understood.
E LOOP GENERATOR (E) a single loop generator to illustrate electromagnetic induc-	In addition to pointing out that an emf is induced in a conductor when there is a relative motion of the conductor and the magnetic field, it should be emphasized that an emf is induced in a coil when the flux linking the coil changes.
ATOR TYPES AND CONNECTION (E) y the connections of shunt, series and compound genera- ake connections and check for build-up.	The potentials developed in the armature coils of all rotating generators (A.C. and D.C.) are alternating in form.
RATION CURVE (E) rmine the saturation curve of a D.C. generator. **ATOR SELF-EXCITATION (E)** y the manner in which a self-excited generator builds up to terminal voltage.	Reasons for failure to build up should be discussed and remedies noted.
CHARACTERISTIC CURVES (E) rmine the operating characteristics of various types of D.C. tors.	The voltage characteristic curve and application of each type of generator should be discussed.
MUTATION (E) y the various methods of improving commutation and show mentally commutation improvement by brush shifting and of interpoles.	Reasons for brush sparking and the remedies for each should be considered.

DIVISION 1: Theory and Test (continued)

UNIT: 1

Section	Topic	Element	C Ref
13.2 D.C. Motors	**132.1 Motor principle**	1321.1 Force on Current-Carrying Conductor within a Magnetic Field 1321.2 Fleming's Hand Rule	121 25 17
	132.2 Construction and internal connections	1322.1 Similar to Generator in Construction 1322.2 Shunt, Series and Compound Connections	13
	132.3 CEMF	1323.1 Generator Action in Armature 1323.2 Significance of cemf 1323.3 Relationship between emf and Motor Speed 1323.4 Starting Current — Need for Series Resistance	11 1 111
	132.4 Operating Characteristics	1324.1 Speed and Torque Characteristics of Each Type 1324.2 Speed Regulation 1324.3 Effects of Armature Reaction 1324.4 Interpoles	13
	132.5 Efficiency of D.C. machines	1325.1 Losses in D.C. Machines 1325.2 Efficiency at Different Loads 1325.3 Name Plate Data	111 17 111 17
	132.6 Dynamic and Regenerative Braking (O)	1326.1 Principle of Using Generator Action to Stop a Motor by Energy Dissipation 1326.2 Principle of Using Generator Action to Stop a Motor by Feedback of Energy Into supply 1326.3 Applications	1211 2325 2413

UNIT: 1.3 D.C. Machines

Topic	Element	Cross-Reference	Fundamentals
.1 Motor principle	1321.1 Force on Current-Carrying Conductor within a Magnetic Field 1321.2 Fleming's Hand Rule	1211.2 251.1 173.1	Properties of Magnetic Lines $F \propto B\ell I$ $T \propto \phi I_a$
.2 Construction and internal connections	1322.1 Similar to Generator in Construction 1322.2 Shunt, Series and Compound Connections	131.3	
.3 CEMF	1323.1 Generator Action in Armature 1323.2 Significance of cemf 1323.3 Relationship between emf and Motor Speed 1323.4 Starting Current — Need for Series Resistance	111.3 13.1 1114.2	$Eg \propto \phi N$ $V = E + IR$
.4 Operating Characteristics	1324.1 Speed and Torque Characteristics of Each Type 1324.2 Speed Regulation 1324.3 Effects of Armature Reaction 1324.4 Interpoles	131.6	Regulation (C) Armature reaction
.5 Efficiency of D.C. machines	1325.1 Losses in D.C. Machines 1325.2 Efficiency at Different Loads 1325.3 Name Plate Data	1116.1 171.8 1116.4 172.5	Efficiency % $= \frac{\text{Output Power (P. out)}}{\text{Input Power (P. in)}} \times 100$ Losses in machines
.6 Dynamic and Regenerative Braking (O)	1326.1 Principle of Using Generator Action to Stop a Motor by Energy Dissipation 1326.2 Principle of Using Generator Action to Stop a Motor by Feedback of Energy Into supply 1326.3 Applications	1211.4 2325.1 2413.4	Energy conversion Feedback (C) Regeneration (C)

Technical Terms	Suggestions for Student Activity	Discu
Torque Force	**MOTOR PRINCIPLE (E)** • illustrate the effect of the force on a current-carrying conductor in a magnetic field and the relationship among directions of flux, current and force.	The principle of a force being exer magnetic field is made use of in i principle upon which a motor opera
Shunt Series Compound	**MOTOR TYPES AND CONNECTIONS (E)** • study the connections for shunt, series and compound motors. Make connections and measure speed.	
Counter Emf	**CEMF OF A MOTOR (E)** Demonstrate motor cemf by connecting a lamp in series with armature of a small shunt motor and observing the lamp brilliance with zero and normal field excitation.	The generator action taking place i
Cumulative connection Differential connection Speed regulation	**MOTOR CHARACTERISTICS (E)** • determine the load characteristics of shunt, series and compound motors.	The effects of armature reaction tics are to be comprehended.
Efficiency	**EFFICIENCY (E)** • determine the efficiency of a shunt motor.	Typical efficiencies of various size the losses which occur in D.C. mac The information given by the name
Dynamic braking Feedback Regenerative braking	**DYNAMIC BRAKING (E)** • observe the dynamic braking of a motor.	

Suggestions for Student Activity	Discussion
TOR PRINCIPLE (E) ustrate the effect of the force on a current-carrying conductor magnetic field and the relationship among directions of flux, ent and force.	The principle of a force being exerted on a conductor carrying current in a magnetic field is made use of in instrument damping as well as being the principle upon which a motor operates.
TOR TYPES AND CONNECTIONS (E) udy the connections for shunt, series and compound motors. e connections and measure speed.	
F OF A MOTOR (E) onstrate motor cemf by connecting a lamp in series with ture of a small shunt motor and observing the lamp brilliance zero and normal field excitation.	The generator action taking place in a motor should be discussed.
TOR CHARACTERISTICS (E) etermine the load characteristics of shunt, series and com- nd motors.	The effects of armature reaction must be considered if motor characteristics are to be comprehended.
CIENCY (E) etermine the efficiency of a shunt motor.	Typical efficiencies of various sizes of D.C. machines should be noted and the losses which occur in D.C. machines discussed. The information given by the name plate should be interpreted.
AMIC BRAKING (E) bserve the dynamic braking of a motor.	

DIVISION 1: Theory and Test

UNIT: 1·4 D.

Section	Topic	Element	C Ref
14.1 Variable voltage speed controls	**141.1 Control by armature voltage**	1411.1 Operating principle	
		1411.2 Merits	
		1411.3 Ward-Leonard System (O)	
		1411.4 Control by series resistor	23
		1411.5 S.C.R. control	222
		1411.6 Applications of control types	
14.2 D.C. constant-potential controls	**142.1 Principle of operation**	1421.1 Purpose: Starting, protecting, jogging, braking and reversing of D.C. motor	13
		1421.2 Speed control of D.C. motors by field current variation	
	142.2 Control devices and circuits	1422.1 Control devices: push-buttons, relays, timers, rheostats, switches	35
		1422.2 Control circuits: Start-stop, jog, reverse and sequence control circuits	
		1422.3 Controllers: manual, time delay, Cemf	

UNIT: 1·4 D.C. Motor Controls

Topic	Element	Cross-Reference	Fundamentals
141.1 Control by armature voltage	1411.1 Operating principle 1411.2 Merits 1411.3 Ward-Leonard System (O) 1411.4 Control by series resistor 1411.5 S.C.R. control 1411.6 Applications of control types	1.3 232.8 2223.6	Range Bidirectional (C) Proportionality (C) $N \propto \frac{E_a}{\phi}$ Angular velocity Torque, $T \propto I_a \phi_p$ Energy conversion Dynamic braking Amplification (C)
142.1 Principle of operation	1421.1 Purpose: Starting, protecting, jogging, braking and reversing of D.C. motor 1421.2 Speed control of D.C. motors by field current variation	132.6	Angular displacement
142.2 Control devices and circuits	1422.1 Control devices: push-buttons, relays, timers, rheostats, switches 1422.2 Control circuits: Start-stop, jog, reverse and sequence control circuits 1422.3 Controllers: manual, time delay, Cemf	354.1	Interlocking Sequencing Feedback (C) Time constant (C) Automation

Technical Terms	Suggestions for Student Activity	Dis
Variable voltage control Range Bidirectional Rheostat	**SPEED CONTROL BY ARMATURE VOLTAGE VARIATION (E)** • measure the speed of a motor for wide variations of armature voltage with the field constant.	Basic circuits which illustrate control should be studied exten lying principles should be consid
Excitation Shunt machine Dynamic braking	**WARD-LEONARD SYSTEM (E) (O)** • study the wide range of speed control available using the Ward-Leonard System.	Students should be given numer tics. An understanding of the ope of its relative obsolescence, pr D.C. machines.
Ward-Leonard System S.C.R. Thyristor	**S.C.R. CONTROL (E)** • measure the speed variation of a D.C. motor which has an S.C.R. unit.	Manufacturers' manuals contain ideal for study and project purp S.C.R. circuits should be observe
	SERIES RESISTOR CONTROL (E) • Measure the speed variation of a D.C. series motor, under load, with a variable series resistor.	
Constant-potential Jogging Speed control	**SPEED CONTROL (E)** • Study the speed control of a shunt motor by field current variation.	D.C. constant-potential control ciated with automatic open loop
Disconnect, contactor Mechanical interlocks Electrical interlocks Time delay relay Thermal overload relay Overcurrent device Sequencing Manual starter Automatic starter Interlocking Cemf starter	**CONSTANT-POTENTIAL CONTROLS (E)** Connect and check the operation of the following: • manual, 3 or 4 point starters • start-stop, forward-reverse, and jog control • time delay starter • Cemf starter • sequence interlocking	This topic provides a study area hardware.

Suggestions for Student Activity	Discussion
CONTROL BY ARMATURE VOLTAGE ION (E) ure the speed of a motor for wide variations of armature with the field constant.	Basic circuits which illustrate the variable voltage methods of speed control should be studied extensively rather than intensively. The underlying principles should be considered in some depth.
LEONARD SYSTEM (E) (O) the wide range of speed control available using the Ward- System.	Students should be given numerous problems involving simple mathematics. An understanding of the operation of a Ward-Leonard System, in spite of its relative obsolescence, provides the student with a good grasp of D.C. machines.
CONTROL (E) ure the speed variation of a D.C. motor which has an S.C.R.	Manufacturers' manuals contain simple S.C.R. control circuits which are ideal for study and project purposes. The performance characteristics of S.C.R. circuits should be observed on an oscilloscope.
RESISTOR CONTROL (E) sure the speed variation of a D.C. series motor, under load, ariable series resistor.	
CONTROL (E) the speed control of a shunt motor by field current varia-	D.C. constant-potential control contains elements which are closely associated with automatic open loop operation.
TANT-POTENTIAL CONTROLS (E) ct and check the operation of the following: ual, 3 or 4 point starters t-stop, forward-reverse, and jog control delay starter f starter uence interlocking	This topic provides a study area rich in concepts and the use of interrelated hardware.

DIVISION 1: Theory and Test

UNIT: 1.4 D. C

Section	Topic	Element	Cr Refe
14.3 Closed-loop regulating systems	**143.1 Theory of operation**	1431.1 Purpose	
		1431.2 Block diagram of typical system	
	143.2 Methods of obtaining feedback signal	1432.1 Tachometer generator	131
		1432.2 IR drop	2325
		1432.3 Voltage dividers	2412
	143.3 Amplification of feedback signal	1433.1 Reference voltage	
		1433.2 Feedback signal	
		1433.3 Feedback signal amplifiers: electronic, magnetic	23 11 11
	143.4 Error correction	1434.1 Nature of error-correcting signal	
		1434.2 Power amplifiers for error-correcting signal: electronic, magnetic	23

UNIT: 1.4 D. C. Motor Controls

Topic	Element	Cross-Reference	Fundamentals
43.1 Theory of operation	1431.1 Purpose 1431.2 Block diagram of typical system		Regulation (C) Closed-loop system
43.2 Methods of obtaining feedback signal	1432.1 Tachometer generator 1432.2 IR drop 1432.3 Voltage dividers	131.1 2325.1 2412.1	Analogs Feedback (C)
43.3 Amplification of feedback signal	1433.1 Reference voltage 1433.2 Feedback signal 1433.3 Feedback signal amplifiers: electronic, magnetic	 232.1 112.5 112.3	Reference datum Amplification (C)
43.4 Error correction	1434.1 Nature of error-correcting signal 1434.2 Power amplifiers for error-correcting signal: electronic, magnetic	 232.2	Stability (C) Hunting (C)

Technical Terms	Suggestions for Student Activity	Dis
Closed loop Regulation Set point		Closed-loop regulating systems control is one example. Feedba system to make connection bet control apparatus. The feedback nature.
Tachometer generator Feedback	**CLOSED-LOOP SYSTEM (E)** • connect and test a closed loop regulating system which employs S.C.R.'s, for example, a motor speed control circuit that includes a tachometer to obtain the feedback signal.	
Reference voltage Error voltage Proportional control Magnetic amplifier Electronic amplifier		In all closed-loop control syste control, the output signal is co value. This error signal may have control element of the system. T is always proportional to the de
Stability Overshoot Hunting		Stability of a system is difficult be large. Error signal amplificatio magnetic amplifiers, rotary ampli

Suggestions for Student Activity	Discussion
	Closed-loop regulating systems are very numerous. The domestic furnace control is one example. Feedback signals are necessary in order for the system to make connection between the system output and the system control apparatus. The feedback signal does not have to be electrical in nature.
LOOP SYSTEM (E) t and test a closed loop regulating system which employs or example, a motor speed control circuit that includes ter to obtain the feedback signal.	
	In all closed-loop control systems which are involved with proportional control, the output signal is compared with some reference or standard value. This error signal may have to be amplified before it is applied to the control element of the system. The error signal regardless of its amplitude is always proportional to the deviation from the set point.
	Stability of a system is difficult to obtain where the error signal tends to be large. Error signal amplification is obtained by many methods: S.C.R.'s, magnetic amplifiers, rotary amplifiers etc.

DIVISION 1: Theory and Test

UNIT: 1.5 Sin

Section	Topic	Element
15.1 Alternating Current	**151.1 Scalar and Vector Quantities**	1511.1 Typical Scalar and Vector Quantities 1511.2 Vector Representation 1511.3 Vector Addition
	151.2 Sine Waves	1512.1 Advantages of A.C. compared to D.C. 1512.2 Generation by simple rotating coil 1512.3 Phasors 1512.4 Instantaneous value 1512.5 Comparative heating effect of A.C. and D.C. 1512.6 Peak, rms and average values
	151.3 Phase Relationships	1513.1 In-Phase and Out-of-Phase Voltages and Currents 1513.2 Graphic Addition of Sine Wave of Same Frequency 1513.3 Vector Addition of voltages or currents of the same frequency

UNIT: 1.5 Single Phase Circuits

Topic	Element	Cross-Reference	Fundamentals
51.1 Scalar and Vector Quantities	1511.1 Typical Scalar and Vector Quantities 1511.2 Vector Representation 1511.3 Vector Addition	2314.2 1522.4 1523.3 1536.3 161.2 171.6 1722.2	Scalar quantity Vector quantity Vectors and vector addition
51.2 Sine Waves	1512.1 Advantages of A.C. compared to D.C. 1512.2 Generation by simple rotating coil 1512.3 Phasors 1512.4 Instantaneous value 1512.5 Comparative heating effect of A.C. and D.C. 1512.6 Peak, rms and average values	131.2 1721.1 151.5 231.1	Faraday's Law Unidirectional flow (C) Bidirectional flow (C) Sinusoidal Waveforms $f = \frac{N \times P}{120}$ Heating effect of Current $e = E_m \sin \theta$
51.3 Phase Relationships	1513.1 In-Phase and Out-of-Phase Voltages and Currents 1513.2 Graphic Addition of Sine Wave of Same Frequency 1513.3 Vector Addition of voltages or currents of the same frequency	2325.1 1535.1 3433.4 1511.3	Phase Relationships Instantaneous values Vector addition

Technical Terms	Suggestions for Student Activity	Disc
Scalar Vector Vector Addition	**VECTOR ADDITION (X)** Problems involving addition of vectors.	The two methods of determining t by graphical methods and by calcu a slide rule should be encouraged.
Alternating Current Sine Sinusoidal Cycle Frequency Hertz Electrical Degrees Peak, rms and average values Phasors	**SINE WAVE (E)** Using an oscilloscope, observe the waveform of an A.C. supply and remove its sinusoidal form. **PLOTTING A SINE WAVE (E)** • plot a sine wave (one cycle) from calculated instantaneous values by rotating vector method.	A rotating vector which has a co velocity is known as a phasor. The relationships between maxi discussed and the significance of e It should be explained why 10-am effect as 10-amperes D.C.
In-Phase Out-of-Phase Phase Angle Displacement Angle	**ADDITION OF TWO SINE WAVES (E)** • add two sine waves of voltage of the same frequency, and observe the resultant wave on an oscilloscope. Both in-phase and out-of-phase conditions should be studied.	The advantages of vector addition solution of problems on A.C. could

Suggestions for Student Activity	Discussion
ADDITION (X) involving addition of vectors.	The two methods of determining the value of the resultant vector, namely by graphical methods and by calculations should be considered. The use of a slide rule should be encouraged.
/E (E) oscilloscope, observe the waveform of an A.C. supply e its sinusoidal form. **A SINE WAVE (E)** sine wave (one cycle) from calculated instantaneous rotating vector method.	A rotating vector which has a constant magnitude and a constant angular velocity is known as a phasor. The relationships between maximum rms and average values should be discussed and the significance of each considered. It should be explained why 10-amperes A.C. (rms) give the same heating effect as 10-amperes D.C.
OF TWO SINE WAVES (E) sine waves of voltage of the same frequency, and ob- esultant wave on an oscilloscope. ase and out-of-phase conditions should be studied.	The advantages of vector addition as compared to graphical addition in the solution of problems on A.C. could be discussed.

Section	Topic	Element	C Re
15.1 Alternating Current (continued)	**151.4 Non-Sinusoidal Waveforms**	1514.1 Graphical Addition of Sine Waves of Different Frequencies to Produce Non-sinusoidal Shapes	
		1514.2 Common Non-sinusoidal Continuous Waveforms	232
		1514.3 Pulse Waveforms	232
	151.5 A.C. Power in a Purely Resistive Circuit	1515.1 Form of power wave	11
		1515.2 Calculation of Average Power	151

UNIT: 1.5 Single Phase Circuits

Topic	Element	Cross-Reference	Fundamentals
151.4 Non-Sinusoidal Waveforms	1514.1 Graphical Addition of Sine Waves of Different Frequencies to Produce Non-sinusoidal Shapes		Composition of Complex Waveforms Continuity (C) Pulses (C)
	1514.2 Common Non-sinusoidal Continuous Waveforms	2325.4	
	1514.3 Pulse Waveforms	2326.1	
151.5 A.C. Power in a Purely Resistive Circuit	1515.1 Form of power wave	111.6	$P = E_{rms} I_{rms}$ (Purely Resistive Circuit)
	1515.2 Calculation of Average Power	1512.5	

Technical Terms	Suggestions for Student Activity	Discu
Non-sinusoidal Pulses	**ALTERNATING CURRENT WAVEFORMS (E)** • observe and measure (using an oscilloscope) A.C. voltages and currents of different frequencies, amplitudes and wave-forms.	The importance of harmonics in po the generation of special wave shap
Power Waveform Instantaneous power Maximum power Average power	**A.C. POWER (E)** • Measure A.C. power for a purely resistive circuit and compare it to the power on the same D.C. voltage.	The effect of harmonics on an audib strated visually by the use of an osci

Suggestions for Student Activity	Discussion
NATING CURRENT WAVEFORMS (E) rve and measure (using an oscilloscope) A.C. voltages rents of different frequencies, amplitudes and wave-forms.	The importance of harmonics in power systems, musical instruments and the generation of special wave shapes should be discussed.
OWER (E) sure A.C. power for a purely resistive circuit and compare e power on the same D.C. voltage.	The effect of harmonics on an audible signal can be simultaneously demonstrated visually by the use of an oscilloscope.

DIVISION 1: Theory and Test

UNIT: 1.5 Sing

Section	Topic	Element	Cr Refe
15.2 Inductance	**152.1 Self-Inductance**	1521.1 Inductance: Definition and Symbol	2
		1521.2 The Unit of Inductance	
		1521.3 Inductive and Non-inductive Windings	
		1521.4 Direction and Magnitude of Induced EMF	17
		1521.5 Factors Affecting Self-Inductance	
		1521.6 Calculating Self-Inductance	
		1521.7 Effect of Core Saturation	1123
	152.2 Current in Circuits Containing Pure Inductance Only	1522.1 D.C. Build-up in Pure R Circuit (Graphical)	
		1522.2 D.C. Build-up in Pure L Circuit (Graphical)	231
		1522.3 Energy of a Magnetic Field	112
		1522.4 Phase Relationships of E and I (A.C.)	151
	152.3 Current in L-R Circuits	1523.1 D.C. Build-up and Decay (Graphical)	1114
		1523.2 L-R Time Constant	
		1523.3 V and I Phase Relationships (A.C.)	

UNIT: 1.5 Single Phase Circuits

Topic	Element	Cross-Reference	Fundamentals
elf-Inductance	1521.1 Inductance: Definition and Symbol	21.3	Induction (C) Principle of electromagnetic induction
	1521.2 The Unit of Inductance		
	1521.3 Inductive and Non-inductive Windings		Faraday's Law: $E_{av} = \frac{\Delta\phi}{\Delta t}$
	1521.4 Direction and Magnitude of Induced EMF	171.3	Lenz's Law $E_{av} = N\frac{\Delta\phi}{\Delta t}$
	1521.5 Factors Affecting Self-Inductance		Induced EMF:
	1521.6 Calculating Self-Inductance		$E_{av} = -L\frac{\Delta I}{\Delta t}$
	1521.7 Effect of Core Saturation	1123.3	$L = \frac{N\phi}{I}$ $L = \frac{N^2\mu A}{\ell}$ Saturation (C)
urrent in ircuits Con- aining Pure nductance Only	1522.1 D.C. Build-up in Pure R Circuit (Graphical)		Newton's Third Law (C)
	1522.2 D.C. Build-up in Pure L Circuit (Graphical)		Lenz's Law
	1522.3 Energy of a Magnetic Field	231.1 112.2	Energy storage Conservation of Energy $W = 1/2\ LI^2$
	1522.4 Phase Relationships of E and I (A.C.)	151.3	Vectorial Representation
urrent in L-R ircuits	1523.1 D.C. Build-up and Decay (Graphical)	1114.2	$E = IR$
	1523.2 L-R Time Constant		Time Constant (C) $\tau = L/R$
	1523.3 V and I Phase Relationships (A.C.)		

Technical Terms	Suggestions for Student Activity	Dis
Inductance: L Permeability: Reluctance Flux Linkages	**EMF OF SELF-INDUCTANCE** • determine the factors affecting the emf of self-induction.	The student should gain an unc ments and by problem solving. The EMF of self-induction can An appreciation of the value of necting a lamp across the te observing the lamp when the reached a stable value. For best
Magnetic Saturation B-H Curve	**LENZ'S LAW (E)** • demonstrate Lenz's Law using a galvanometer connected across the terminals of a coil.	Lenz's Law may be considered a namely, action and reaction are e It should also be noted that Lenz of energy. The fact that the cur expenditure of energy to produc evident in most types of electrica
Counter emf Joule Lagging and leading current Time Constant Phasors	**CURRENT BUILDUP IN R AND L CIRCUITS (E)** Study the current buildup in • a circuit which is pure R. • a circuit which is highly inductive. **SERIES L-R CIRCUIT (E)** • Using an electronic switch and scope or dual-beam scope observe the device voltages and their phase relationships for R and L in series. • measure the circuit and device voltages on A.C. • represent these vectorially.	The energy of a magnetic field r the circuit of a large inductance also be demonstrated. This could The application of L-R time const
Inductance: L Permeability: Reluctance Flux Linkages Magnetic Saturation B-H Curve		

Suggestions for Student Activity	Discussion
F OF SELF-INDUCTANCE determine the factors affecting the emf of self-induction.	The student should gain an understanding of inductance both by experiments and by problem solving. The EMF of self-induction can be demonstrated by simple experiments. An appreciation of the value of the induced emf can be obtained by connecting a lamp across the terminal of a fairly large inductance and observing the lamp when the circuit is interrupted after the A.C. has reached a stable value. For best results use a carbon filament lamp.
NZ'S LAW (E) demonstrate Lenz's Law using a galvanometer connected across terminals of a coil.	Lenz's Law may be considered as an application of the principle in physics, namely, action and reaction are equal and opposite. It should also be noted that Lenz's Law is based on the law of conservation of energy. The fact that the currents resulting from induction require an expenditure of energy to produce them is an important principle which is evident in most types of electrical machinery.
RRENT BUILDUP IN R AND L CIRCUITS (E) udy the current buildup in a circuit which is pure R. a circuit which is highly inductive. **RIES L-R CIRCUIT (E)** Using an electronic switch and scope or dual-beam scope ob-rve the device voltages and their phase relationships for R and n series. measure the circuit and device voltages on A.C. represent these vectorially.	The energy of a magnetic field may be dramatically illustrated by opening the circuit of a large inductance and observing arc. Magnetic blowout can also be demonstrated. This could be the basis of discussion. The application of L-R time constant could be considered.

Section	Topic	Element	Cro Refer
15.2 Inductance (continued)	**152.4 Inductive Reactance**	1524.1 Comparison of Opposition of an Inductor to A.C. and D.C.	152.
		1524.2 Unit and Symbol	171.
		1524.3 Explanation of Inductive Reactance: Factors Affecting	215. 152.
	152.5 Power Factor	1525.1 Power Waveforms in inductive Circuits	151. 1116.
		1525.2 Definition and Calculation of P.F.	
		1525.3 Power Measurement by Wattmeter	122.
	152.6 Low Frequency Inductors	1526.1 Construction and Design	2131.
		1526.2 Selection for Specific Application	
	152.7 Series and Parallel Connections	1527.1 Inductances in Series (No Coupling)	1114.3 1114.4
		1527.2 Inductances in Parallel (No Coupling)	
	152.8 Impedance	1528.1 Definition, Unit and Symbol of Impedance	
		1528.2 Impedance of an L-R series circuit: Vector diagram	1114.2
		1528.3 Impedance of an L-R parallel circuit; Vector diagram	1511.2 1523.3

UNIT: 1.5 Single Phase Circuits

Topic	Element	Cross-Reference	Fundamentals
152.4 Inductive Reactance	1524.1 Comparison of Opposition of an Inductor to A.C. and D.C. 1524.2 Unit and Symbol 1524.3 Explanation of Inductive Reactance: Factors Affecting	152.1 171.6 215.2 152.8	$V = IR$ $V_L = IX_L$ $X_L = 2\pi fL$
152.5 Power Factor	1525.1 Power Waveforms in inductive Circuits 1525.2 Definition and Calculation of P.F. 1525.3 Power Measurement by Wattmeter	151.5 1116.3 122.4	Conservation of Energy Power Factor $= \frac{P}{VI} = \cos\theta$
152.6 Low Frequency Inductors	1526.1 Construction and Design 1526.2 Selection for Specific Application	2131.2	
152.7 Series and Parallel Connections	1527.1 Inductances in Series (No Coupling) 1527.2 Inductances in Parallel (No Coupling)	1114.3 1114.4	$L = L_1 + L_2 \ldots . L_N$ $L = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \ldots . \frac{1}{L_N}}$
152.8 Impedance	1528.1 Definition, Unit and Symbol of Impedance 1528.2 Impedance of an L-R series circuit: Vector diagram 1528.3 Impedance of an L-R parallel circuit; Vector diagram	1114.2 1511.2 1523.3	Ohm's Law: $Z = E/I$ $Z = \sqrt{R^2 + X_L^2}$ Impedance (C)

Technical Terms	Suggestions for Student Activity	Disc
Inductive Reactance (X_L) Lagging Phase Angle	**INDUCTIVE REACTANCE (E)** • Study inductive reactance at different frequencies and values of inductance.	The student should understand th greater opposition to A.C. than to D The formula $X_L = 2\pi fl$ should be d
Energy Power Wattmeter Negative Power; Peak Power Power Factor	**POWER MEASUREMENT (E)** • Measure power and calculate power factor for resistive and inductive circuits.	Disadvantages of poor power facto
Inductor Lamination Air Gap	**PRACTICAL INDUCTANCES (A)** • Compare the design features of inductors for different applications.	Examples of commercial use of lo
Coupling	**INDUCTANCE IN SERIES AND PARALLEL (E)** • Measure total inductance of • series inductances. • parallel inductances.	This topic may be treated extensiv
Impedance	**IMPEDANCE (E)** • Determine the impedance of a series and a parallel L-R circuit. Circuit and device quantities should be measured and vector diagrams drawn.	Solution by vectors is recommend

Suggestions for Student Activity	Discussion
E REACTANCE (E) ductive reactance at different frequencies and values of .	The student should understand the mechanism by which a coil affords a greater opposition to A.C. than to D.C. The formula $X_L = 2\pi fl$ should be derived.
EASUREMENT (E) power and calculate power factor for resistive and ircuits.	Disadvantages of poor power factor should be appreciated.
L INDUCTANCES (A) the design features of inductors for different appli-	Examples of commercial use of low frequency inductors may be given.
ICE IN SERIES AND PARALLEL (E) total inductance of ductances. inductances.	This topic may be treated extensively rather than intensively.
CE (E) ne the impedance of a series and a parallel L-R circuit. d device quantities should be measured and vector rawn.	Solution by vectors is recommended.

Section	Topic	Element	Cro Refer
15.3 Capacitance	**153.1 Elementary Capacitor**	1531.1 Definition and Unit of Capacitance	
		1531.2 Types and construction	21.
		1531.3 Principle of Operation	111. 111.
		1531.4 Factors Affecting Capacitance	
		1531.5 Dielectric constants and strengths	1115.
	153.2 Construction and Characteristics of Commercial Capacitors	1532.1 Solid Dielectric	1115.
		1532.2 Electrolytic	
		1532.3 Oil-Filled	1545.
		1532.4 Applications	3622. 231. 232. 2412.
	153.3 Series and parallel connections	1533.1 Derivation of Series and Parallel Formulae	1114. 1114.
		1533.2 Reasons for Series and Parallel Connections	
		1533.3 Voltage Distribution Across Series String	
	153.4 Time Constant	1534.1 Exponential Charge and Discharge Curves	
		1534.2 Time Constant for a C-R Circuit	1523.2 231.1
		1534.3 Universal Time Constant Curves	2321.3 2321.5 2325.4

UNIT: 1.5 Single Phase Circuits

Topic	Element	Cross-Reference	Fundamentals
Elementary Capacitor	1531.1 Definition and Unit of Capacitance		Energy Storage
	1531.2 Types and construction	21.4	$Q = CE$
	1531.3 Principle of Operation	111.1 111.2	$C \propto \frac{KA}{d}$
	1531.4 Factors Affecting Capacitance		
	1531.5 Dielectric constants and strengths	1115.3	Insulators
Construction and Characteristics of Commercial Capacitors	1532.1 Solid Dielectric	1115.3	Electrolytes
	1532.2 Electrolytic		
	1532.3 Oil-Filled	1545.3	
	1532.4 Applications	3622.3 231.1 232.5 2412.2	
Series and parallel connections	1533.1 Derivation of Series and Parallel Formulae	1114.3 1114.4	$C = C_1 + C_2 + \ldots C_n$ $C = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \cdots \frac{1}{C_n}}$
	1533.2 Reasons for Series and Parallel Connections		
	1533.3 Voltage Distribution Across Series String		
Time Constant	1534.1 Exponential Charge and Discharge Curves		Exponential Growth and Decay
	1534.2 Time Constant for a C-R Circuit	1523.2 231.1	Time Constant $\tau = CR$
	1534.3 Universal Time Constant Curves	2321.3 2321.5 2325.4	

Technical Terms	Suggestions for Student Activity	Disc
Capacitance; Capacitor Farad Electrostatic Field Dielectric Dielectric Constant Dielectric Strength Breakdown Voltage	**CAPACITOR CONSTRUCTION (P)** • Construct and Test a Simple Capacitor.	The actions taking place as a cap emphasized.
Mica Ceramic Plastic Electrolytic Oil-Filled Polarized Non-polarized	**TYPES OF CAPACITORS (A)** • Examine and Compare Different Types of Capacitors.	
	SERIES AND PARALLEL CAPACITANCE (E) • Measure the Capacitance of Known Capacitors in Series and Parallel.	The pupils should solve problem vidual capacitors in series across
Exponential Time Constant Universal Curves	**TIME CONSTANT (E)** • Study Time Constant of C-R Circuits.	The application of time constants makes an interesting study.

Suggestions for Student Activity	Discussion
OR CONSTRUCTION (P) uct and Test a Simple Capacitor.	The actions taking place as a capacitor charges and discharges should be emphasized.
F CAPACITORS (A) e and Compare Different Types of Capacitors.	
ND PARALLEL CAPACITANCE (E) e the Capacitance of Known Capacitors in Series and	The pupils should solve problems determining the voltages across individual capacitors in series across a voltage supply (both A.C. and D.C.).
NSTANT (E) ime Constant of C-R Circuits.	The application of time constants in relaxation oscillators and photo timers makes an interesting study.

Section	Topic	Element	Cr Refe
15.3 Capacitance (continued)	**153.5 Capacitive Reactance**	1535.1 Voltage and Current Waves for Pure Capacitance; Phase Relationship, vector diagram	151
		1535.2 Explanation of Capacitive Reactance; Factors Affecting	
		1535.3 Definition, Unit and Symbol	
	153.6 Impedance of C-R Circuit	1536.1 Voltage Drops in a C-R Series Circuit; Vector Diagram	
		1536.2 Calculation of Impedance	
		1536.3 Impedance of a C-R Parallel circuit: Vector diagram	
15.4 Series and Parallel Circuits	**154.1 L-C-R series circuit**	1541.1 Impedance	152.
		1541.2 Device Voltages; Vector Diagram	1114.
		1541.3 Net Reactive voltage	
		1541.4 Power and power factor	
	154.2 Series Resonance	1542.1 Conditions for Resonance	1544. 232.
		1542.2 Resonance Curves	232.
		1542.3 Circuit power	151.
		1542.4 Applications	1545.

Test

UNIT: 1.5 Single Phase Circuits

Topic	Element	Cross-Reference	Fundamentals
153.5 Capacitive Reactance	1535.1 Voltage and Current Waves for Pure Capacitance; Phase Relationship, vector diagram 1535.2 Explanation of Capacitive Reactance; Factors Affecting 1535.3 Definition, Unit and Symbol	151.3	Phase Relationships $X_c = \frac{1}{2\pi fC}$ $E_c = IX_c$ $X_c = \frac{E_c}{I_c}$
153.6 Impedance of C-R Circuit	1536.1 Voltage Drops in a C-R Series Circuit; Vector Diagram 1536.2 Calculation of Impedance 1536.3 Impedance of a C-R Parallel circuit: Vector diagram		Impedance (C) $Z = \sqrt{R^2 + X_c^2}$ $Z = \frac{E}{I}$
54.1 L-C-R series circuit	1541.1 Impedance 1541.2 Device Voltages; Vector Diagram 1541.3 Net Reactive voltage 1541.4 Power and power factor	152.8 1114.3	$I = \frac{E}{Z}$ $Z = \sqrt{R^2 + (X_L - X_c)^2}$ Phase relationships $X = X_L - X_c$ $P.F. = \frac{R}{Z} = \cos\theta$ Vector Representation $P = EI \cos\theta$
54.2 Series Resonance	1542.1 Conditions for Resonance 1542.2 Resonance Curves 1542.3 Circuit power 1542.4 Applications	1544.1 232.4 232.5 151.5 1545.1	Resonance (C) $\left.\begin{matrix} X_L = X_c \\ E_L = E_c \end{matrix}\right\\}$ for f_r $f_r = \frac{1}{2\pi\sqrt{LC}}$

Technical Terms	**Suggestions for Student Activity**	
Leading Current Capacitive Reactance	**CAPACITIVE REACTANCE (E)** • Study the Effect of Frequency and Capacitance on Capacitive Reactance.	The formula for capaciti concepts.
Impedance	**SERIES AND PARALLEL C-R CIRCUITS (E)** • Measure device and circuit voltages and currents. • Calculate the impedance for each circuit. • Draw vector diagram for each circuit.	
Net Reactance Reactive Voltage Net reactive voltage Power factor	**SERIES L-C-R CIRCUIT (E)** • Measure Device Voltages and Current. • Determine the Circuit Voltage by Vector diagram. • Measure power and determine power factor.	Problem solving should b the relationships involved The solution of problems, should be stressed. The voltage should be noted. Devices used in experime to illustrate dramatically t greatly exceed their vecto The advantages and disa cussed. Typical curves fo effect of resistance on the
Resonant frequency Series Resonance Selectivity Resonance Curves (Z & I)	**SERIES RESONANCE (E)** • Demonstrate Resonant Effects in a Series L-C-R Circuit.	

Suggestions for Student Activity	Discussion
IVE REACTANCE (E) the Effect of Frequency and Capacitance on Capacitive e.	The formula for capacitive reactance should be developed from basic concepts.
ND PARALLEL C-R CIRCUITS (E) e device and circuit voltages and currents. te the impedance for each circuit. ector diagram for each circuit.	
C-R CIRCUIT (E) e Device Voltages and Current. ine the Circuit Voltage by Vector diagram. e power and determine power factor.	Problem solving should be stressed to ensure that the pupils understand the relationships involved in series and parallel L-R and C-R circuits. The solution of problems on L-C-R series circuits by the use of vectors should be stressed. The fact that reactive voltages may exceed circuit voltage should be noted. Devices used in experiment on the L-C-R series circuit should be selected to illustrate dramatically that the arithmetic sum of the device voltage may greatly exceed their vector sum. The advantages and disadvantages of series resonance should be discussed. Typical curves for series resonance should be considered and the effect of resistance on them noted.
ESONANCE (E) strate Resonant Effects in a Series L-C-R Circuit.	

Section	Topic	Element
15.4 Series and Parallel Circuits (continued)	**154.3 L-C-R Parallel Circuit**	1543.1 Device Currents and Vector diagram 1543.2 Net Reactive Current 1543.3 Impedance
	154.4 Parallel Resonance	1544.1 Conditions for Resonance 1544.2 Resonance Curves
	154.5 Power in L-C-R Circuits	1545.1 Analysis of Circuit Power 1545.2 Measurement of Circuit Power 1545.3 Power Factor Improvement; Desirable Effects

UNIT: 1.5 Single Phase Circuits

Topic	Element	Cross-Reference	Fundamentals
54.3 L-C-R Parallel Circuit	1543.1 Device Currents and Vector diagram	1114.4	$I = I_r + I_c + I_L$ (Vector Sum)
	1543.2 Net Reactive Current		Reactive $I = I_L - I_c$
	1543.3 Impedance	152.8	$Z = E/I$
54.4 Parallel Resonance	1544.1 Conditions for Resonance	232.4	Resonance (C)
	1544.2 Resonance Curves	232.5 1542.1	$\left.\begin{matrix} I_c = I_L \\ X_c = X_L \end{matrix}\right\}$ for f_r
54.5 Power in L-C-R Circuits	1545.1 Analysis of Circuit Power	1116.1	$P = EI \cos\theta$ Power Factor $= \cos\theta = \frac{P}{EI}$
	1545.2 Measurement of Circuit Power	1116.3 1224.3	
	1545.3 Power Factor Improvement; Desirable Effects	152.5 1532.4	

Technical Terms	Suggestions for Student Activity	Discus
Reactive Current Quadrature Current	**PARALLEL L-C-R CIRCUIT (E)** • Measure device currents and voltage. • Determine circuit current vectorially.	
Resonant Frequency Antiresonance		The characteristics of series and p compared. Power factor improvement may be ill Problems on power factor improvem L-C-R circuit conditions.
Volt-amperes Vars Reactive and Active Components	**POWER FACTOR (E)** • Measure power and determine power factor in L-C-R circuits (parallel). • Improve power factor, using capacitors.	

Suggestions for Student Activity	Discussion
L-C-R CIRCUIT (E) e device currents and voltage. ine circuit current vectorially.	
	The characteristics of series and parallel resonance circuits should be compared. Power factor improvement may be illustrated by a vector diagram. Problems on power factor improvement assist the pupils in understanding L-C-R circuit conditions.
ACTOR (E) e power and determine power factor in L-C-R circuits power factor, using capacitors.	

Section	Topic	Element
16.1 Three-phase Fundamentals	161.1 Three-Phase Wave Forms	1611.1 Advantages of polyphase systems 1611.2 Elementary Alternator 1611.3 Vector Representation
	161.2 Star and Delta Connections	1612.1 Analysis of Star Connection; Vector Diagram 1612.2 Analysis of Delta Connection; Vector Diagram
	161.3 Three-Phase Power	1613.1 Phase and circuit powers at unity P.F. and at P.F. Less than one for: • balanced star • balanced delta 1613.2 Measurement of Three-Phase Power by • three-wattmeter method • two-wattmeter method 1613.3 Analysis of Two-Wattmeter Method, Using Vector Diagrams

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UNIT: 1.6 Three-Phase Circuits

Topic	Element	Cross-Reference	Fundamentals
1 Three-Phase Wave Forms	1611.1 Advantages of polyphase systems 1611.2 Elementary Alternator 1611.3 Vector Representation	151.2 172.2 151.3	Polyphase systems Principle of electromagnetic induction Phase displacements
2 Star and Delta Connections	1612.1 Analysis of Star Connection; Vector Diagram 1612.2 Analysis of Delta Connection; Vector Diagram	343.1 344.4 171.12	Star Connection: Line E = $\sqrt{3}$ x Phase E Line I = Phase I Delta Connection: Line E = Phase E Line I = $\sqrt{3}$ x Phase I
3 Three-Phase Power	1613.1 Phase and circuit powers at unity P.F. and at P.F. Less than one for: • balanced star • balanced delta 1613.2 Measurement of Three-Phase Power by • three-wattmeter method • two-wattmeter method 1613.3 Analysis of Two-Wattmeter Method, Using Vector Diagrams	343.5 122.4 1511.2	Power (C) Three-Phase P = $\sqrt{3}EI \cos\theta$ Circuit P.F. = $\cos\theta = \frac{P}{\sqrt{3}EI}$ $P_2 = EI \cos(30 - \theta)$ $P_1 = EI \cos(30 + \theta)$ Three-Phase P = $W_1 + W_2$

Technical Terms	Suggestions for Student Activity	Discu
Polyphase Voltages Two-phase Three-phase Six-phase	**THREE-PHASE ALTERNATOR (E)** • observe on an oscilloscope the waveforms available from the various terminals of a Three-Phase Alternator.	Electronic switches may be used t
Star; Wye Delta Line and Phase quantities Phase Angle	**STAR CONNECTION (E)** • measure Phase and Line Values of E and I with a balanced resistive load. **DELTA CONNECTION (E)** • measure Phase and Line Values of E and I with a balanced resistive load.	Problems should be given to the p resistors to illustrate the relation quantities. These relationships m vector diagrams for resistors conn Three-phase power measurement confirmed by analysis of the vect
Vars Phase Power Circuit Power Circuit Power Factor Phase Angle	**MEASUREMENT OF THREE-PHASE POWER (E)** • measure three-phase power of balanced loads by three-wattmeter and two-wattmeter methods.	

Suggestions for Student Activity	Discussion
REE-PHASE ALTERNATOR (E) observe on an oscilloscope the waveforms available from the rious terminals of a Three-Phase Alternator.	Electronic switches may be used to show polyphase voltages on a scope.
AR CONNECTION (E) measure Phase and Line Values of E and I with a balanced resis- e load. **LTA CONNECTION (E)** measure Phase and Line Values of E and I with a balanced resis- e load.	Problems should be given to the pupils on star and delta connections of resistors to illustrate the relationships existing between line and phase quantities. These relationships may be further emphasized by drawing vector diagrams for resistors connected in star and delta connections. Three-phase power measurement by two and three-wattmeters may be confirmed by analysis of the vector diagram and the connection diagram.
EASUREMENT OF THREE-PHASE POWER (E) measure three-phase power of balanced loads by three-watt- eter and two-wattmeter methods.	

Section	Topic	Element	Cros Refere
16.2 Polyphase power rectification	**162.1 Three-phase rectifier systems**	1621.1 Advantages of three-phase systems compared to single-phase	221.1
		1621.2 Connections and theory of operation of a three-phase system	231.1
		1621.3 Voltage and current waveforms	161.2
	162.2 Six-phase rectifier systems (O)	1622.1 Advantages of six-phase systems compared to three-phase	162.1
		1622.2 Phase conversion	
		1622.3 Use of transformers to convert three-phase to six-phase	
		1622.4 Connections for a complete six-phase rectifier system	
		1622.5 Study of voltage and current waveforms	
		1622.6 Types of power rectifiers	

UNIT: 1.6 Three-Phase Circuits

Topic	Element	Cross-Reference	Fundamentals
1 Three-phase rectifier systems	1621.1 Advantages of three-phase systems compared to single-phase	221.1	Rectification (C) Unidirectional flow (C) Switching (C) Frequency multiplier
	1621.2 Connections and theory of operation of a three-phase system	231.1	
	1621.3 Voltage and current waveforms	161.2	
2 Six-phase rectifier systems (O)	1622.1 Advantages of six-phase systems compared to three-phase	162.1	Phase transformation
	1622.2 Phase conversion		
	1622.3 Use of transformers to convert three-phase to six-phase		
	1622.4 Connections for a complete six-phase rectifier system		
	1622.5 Study of voltage and current waveforms		
	1622.6 Types of power rectifiers		

Technical Terms	Suggestions for Student Activity	Dis
Rectifiers Three-phase rectifiers Ripple Ripple frequency	**THREE-PHASE RECTIFICATION (E) (O)** • connect a three-phase rectifier system. • observe and record the voltage and current waveforms.	Multi-phase power supplies are equipment is largely being replac The study of a typical three-ph should be drawn showing the p load voltage and current.
Phase transformation	**SIX-PHASE RECTIFICATION (E)** • connect transformers for three-phase to six-phase transformation. • connect a six-phase rectifier system. • observe and record the voltage and current waveforms.	Vector diagrams may be drawn t from transformers supplied by a th Emphasis on this topic should version.

Suggestions for Student Activity	Discussion
SE RECTIFICATION (E) (O) three-phase rectifier system. nd record the voltage and current waveforms.	Multi-phase power supplies are more widely used than formerly. Rotary equipment is largely being replaced by static equipment for sources of D.C. The study of a typical three-phase rectifier is recommended and waves should be drawn showing the phase voltages and currents as well as the load voltage and current.
RECTIFICATION (E) ransformers for three-phase to six-phase transfor- six-phase rectifier system. nd record the voltage and current waveforms.	Vector diagrams may be drawn to show that six-phases may be obtained from transformers supplied by a three-phase system. Emphasis on this topic should centre around the theory of phase conversion.

DIVISION 1: Theory and Test

UNIT

Section	Topic	Element
17.1 Iron-core Transformers	**171.1 Mutual Induction**	1711.1 Transfer of energy via changing magnetic field 1711.2 Relationship between magnetizing current and induced emf's
	171.2 Construction and Function of parts	1712.1 Schematic 1712.2 Functions of components 1712.3 Factors governing size of components 1712.4 Air and Liquid cooling
	171.3 Turn and Voltage Ratios	1713.1 Primary counter emf equals applied emf 1713.2 Turns per volt 1713.3 Turns ratio 1713.4 Step-down and step-up transformers 1713.5 General transformer equation
	171.4 Operation under load	1714.1 Explanation of primary current increases 1714.2 Factors limiting maximum load 1714.3 Voltage regulation
	171.5 Current Ratios	1715.1 Derivation of current ratios from $P_{in} = P_{out}$ 1715.2 Current ratio and wire size
	171.6 Vector Diagram Analysis (O)	1716.1 Magnetizing current 1716.2 Vector diagram for unloaded transformer 1716.3 Vector diagram for loaded transformer
	171.7 Losses	1717.1 Factors governing copper loss 1717.2 Explanation of eddy current losses 1717.3 Reduction of eddy current losses 1717.4 Explanation of hysteresis losses 1717.5 Reduction of hysteresis losses

Test

UNIT: 1.7 A. C. Machines

Topic	Element	Cross-Reference	Fundamentals
71.1 Mutual Induction	1711.1 Transfer of energy via changing magnetic field	1113.3	Principle of electromagnetic induction Faraday's Law: $E_{av} \propto \frac{\Delta\phi}{\Delta t}$
	1711.2 Relationship between magnetizing current and induced emf's	112.2	
71.2 Construction and Function of parts	1712.1 Schematic	34.4	
	1712.2 Functions of components		
	1712.3 Factors governing size of components		
	1712.4 Air and Liquid cooling		
71.3 Turn and Voltage Ratios	1713.1 Primary counter emf equals applied emf	1521.4	$N_p/N_s = E_p/E_s$
	1713.2 Turns per volt	232.2	
	1713.3 Turns ratio		$E = 4.44fNB_m A_c$
	1713.4 Step-down and step-up transformers	231.1	
	1713.5 General transformer equation	112.5	
71.4 Operation under load	1714.1 Explanation of primary current increases	344.1 3416.6	Regulation (C) $\% \text{ V.R.} = \frac{E_{nl} - E_{fl}}{E_{fl}} \times 100\%$
	1714.2 Factors limiting maximum load	1315.2 231.1	
	1714.3 Voltage regulation	172.6	
71.5 Current Ratios	1715.1 Derivation of current ratios from $P_{in} = P_{out}$		$I_p/I_s = N_s/N_p$
	1715.2 Current ratio and wire size	1115.2	
71.6 Vector Diagram Analysis (O)	1716.1 Magnetizing current	1511.2	Vectorial Representation
	1716.2 Vector diagram for unloaded transformer	1511.3	
	1716.3 Vector diagram for loaded transformer	151.3	
71.7 Losses	1717.1 Factors governing copper loss		Copper and core losses Electromagnetic Induction Modes of Heat Transfer
	1717.2 Explanation of eddy current losses	1325.1	
	1717.3 Reduction of eddy current losses	2425.2 172.4	
	1717.4 Explanation of hysteresis losses	1123.4	
	1717.5 Reduction of hysteresis losses		

Technical Terms	Suggestions for Student Activity	Di
Transformer Electromagnetic induction Mutual induction Primary winding; Secondary		This section is meant to give t former theory. The transformer is seen as a magnetic induction in which Far losses, determines the particula on the current rating, as it is tance of heat dissipation should The implications of the genera derived by the teacher) should trical features of iron-core tr Several problems based upon th Voltage regulation has probably D.C. generators. The role of lea introduced as a mandatory topic For many of the transformer e formers of a few hundred volt-a
Core, shell construction Laminations Grain-oriented materials Wound-core construction	**TRANSFORMER PROJECT (P) (O)** • construct a small transformer.	
Step-down and step-up Transformation ratio Flux density Turns-Per-Volt B_m — max. flux density A_c — cross-sectional area of core	**TRANSFORMER ACTION FOR UNLOADED CONDITION (E)** • verify the relationship between voltage and turn ratios.	
Voltage regulation No-Load Full-Load Leakage reactance	**TRANSFORMER ACTION UNDER LOAD CONDITIONS (E)** • confirm current and turn relationship. • measure voltage regulation for a particular transformer.	
Magnetizing current		If time permits, complete vect very effective means by which Saturation and Hysteresis eff properly connected oscilloscope
Eddy currents Hysteresis; hysteresis loops Temperature rise Ambient temperature Temperature units: C° Hot-Spot Convection, conduction, radiatio	**TRANSFORMER LOSSES (E) (O)** • measure copper and core losses.	

uggestions for Student Activity	Discussion
	This section is meant to give the student an introduction to basic transformer theory. The transformer is seen as an application of the principle of electromagnetic induction in which Faraday's Law, along with the copper and core losses, determines the particulars of its operation. Heat is a limiting factor on the current rating, as it is in most electrical devices and the importance of heat dissipation should be emphasized. The implications of the general transformer equation (which should be derived by the teacher) should be fully discussed. The physical and electrical features of iron-core transformers are implicit in the equation. Several problems based upon the equation should be assigned. Voltage regulation has probably been taught previously during the study of D.C. generators. The role of leakage reactance in voltage regulation is not introduced as a mandatory topic. For many of the transformer experiments, single and three-phase transformers of a few hundred volt-amperes are very useful.
ER PROJECT (P) (O) small transformer.	
ER ACTION FOR UNLOADED CONDITION (E) elationship between voltage and turn ratios.	
ER ACTION UNDER LOAD CONDITIONS (E) rent and turn relationship. ltage regulation for a particular transformer.	
	If time permits, complete vector analysis of the loaded transformer is a very effective means by which transformer operation may be understood. Saturation and Hysteresis effects can be demonstrated clearly with a properly connected oscilloscope.
ER LOSSES (E) (O) pper and core losses.	

Section	Topic	Element
17.1 Iron-core Transformers (continued)	**171.7 Losses (continued)**	1717.6 Factors governing temperature rise 1717.7 Practical cooling methods 1717.8 Temperature measurement
	171.8 Efficiency and Ratings	1718.1 Definition of Efficiency 1718.2 Factors governing eff'y 1718.3 All-day efficiency 1718.4 Name Plate Data
	171.9 Single-Phase Connections	1719.1 Determination of polarity 1719.2 Series and parallel connection of windings 1719.3 Purpose of Taps; circuit diagrams
	171.10 Auto-transformer	171.10.1 Construction 171.10.2 Analysis of operation 171.10.3 Advantages and disadvantages; applications
	171.11 Instrument Transformers (O)	171.11.1 Need for potential transformers 171.11.2 Standard secondary voltage 171.11.3 Construction, particularly insulation 171.11.4 Theory of current transformers 171.11.5 Standard secondary current 171.11.6 Construction 171.11.7 Use of instrument transformers; safety considerations
	171.12 Polyphase Connections	171.12.1 Circuit diagrams for delta and wye combinations 171.12.2 Vector diagram analysis 171.12.3 Available Voltage ratios

UNIT: 1.7 A. C. Machines

Topic	Element	Cross-Reference	Fundamentals
7 Losses (continued)	1717.6 Factors governing temperature rise 1717.7 Practical cooling methods 1717.8 Temperature measurement	344.2	Heat transfer
8 Efficiency and Ratings	1718.1 Definition of Efficiency 1718.2 Factors governing eff'y 1718.3 All-day efficiency 1718.4 Name Plate Data	132.5 111.6 344.3	% Efficiency $= P_o/P_i \times 100$ $= \frac{P_i - \text{losses}}{P_i} \times 100$ Conservation of energy
9 Single-Phase Connections	1719.1 Determination of polarity 1719.2 Series and parallel connection of windings 1719.3 Purpose of Taps; circuit diagrams	1114.1 344.4	Polarization (C)
10 Auto-transformer	171.10.1 Construction 171.10.2 Analysis of operation 171.10.3 Advantages and disadvantages; applications	171.3 3441.3 355.3	
11 Instrument Transformers (O)	171.11.1 Need for potential transformers 171.11.2 Standard secondary voltage 171.11.3 Construction, particularly insulation 171.11.4 Theory of current transformers 171.11.5 Standard secondary current 171.11.6 Construction 171.11.7 Use of instrument transformers; safety considerations	171.3 12.2	
12 Polyphase Connections	171.12.1 Circuit diagrams for delta and wye combinations 171.12.2 Vector diagram analysis 171.12.3 Available Voltage ratios	344.4 161.2 162.1 355.5	Vectorial representation Delta: $E = E$ phase $I = \sqrt{3}\, I$ phase Wye: $I = I$ phase $E = \sqrt{3}\, E$ phase

Technical Terms	Suggestions for Student Activity	
Thermocouple		The pupils should apprecia rating can be improved by m The conservation of energy efficiency.
Efficiency K.V.A. Temperature Rise	**TRANSFORMER EFFICIENCY (E)** • measure transformer efficiency under different loading conditions.	Time may permit only one m The high voltages which may stringent safety precautions A multitude of interesting p ings and connections are po of mathematical relationshi subject matter.
Polarity	**TRANSFORMER POLARITY (E)** • determine transformer polarity. • connect single-phase transformers in series and parallel.	
Auto-Transformer Isolation Transformer Variable Auto-transformer "Variac", "Powerstat"	**AUTO-TRANSFORMER (E)** • study the operation of an auto-transformer under varying loads.	
Instrument Transformer Current and Potential Transformers Burden		Safety should be stressed in Various small transformers trical features. The teacher insulation, lamination, thick design features.
Wye connection Delta connection	**THREE-PHASE CONNECTIONS (E)** • connect three single-phase transformers in three-phase configurations. **TRANSFORMER TYPES (A)** • compare several different types of Transformers.	

ıggestions for Student Activity	Discussion
	The pupils should appreciate the extent by which a transformer's load rating can be improved by means of each cooling method. The conservation of energy is perhaps the best way to convey the idea of efficiency. Time may permit only one method of polarity checking. The high voltages which may exist in student experiments dictate the most stringent safety precautions. A multitude of interesting problems relating to transformer efficiency, ratings and connections are possible. This is an area in which the importance of mathematical relationships can be stressed and integrated with the subject matter.
ER EFFICIENCY (E) ansformer efficiency under different loading con-	
ER POLARITY (E) transformer polarity. gle-phase transformers in series and parallel.	
FORMER (E) peration of an auto-transformer under varying loads.	
	Safety should be stressed in the use of instrument transformers. Various small transformers can be compared as to their physical and electrical features. The teacher should point out features such as wire size, insulation, lamination, thickness, core area and the reason for some of the design features.
CONNECTIONS (E) ee single-phase transformers in three-phase con- **ER TYPES (A)** veral different types of Transformers.	

Section	Topic	Element
	171.13 Open-delta (O)	171.13.1 Circuit diagram 171.13.2 Theory of operation — vector diagram 171.13.3 Advantages and disadvantages
17.2 Alternators	**172.1 Single-phase alternators — construction and operation**	1721.1 Simple alternator with stationary field 1721.2 Waveform generated 1721.3 Construction of alternator with rotating D.C. field 1721.4 Control of voltage and frequency
	172.2 Three-phase alternators — parts & construction	1722.1 Construction details 1722.2 Waveforms and phasor diagrams 1722.3 Advantages of three-phase

UNIT: 1.7 A. C. Machines

Topic	Element	Cross-Reference	Fundamentals
1.13 Open-delta (O)	171.13.1 Circuit diagram	3553.4	Open-delta
	171.13.2 Theory of operation — vector diagram		
	171.13.3 Advantages and disadvantages		
2.1 Single-phase alternators — construction and operation	1721.1 Simple alternator with stationary field	1113.3 131.2	Electromagnetic induction Faradays Law: $E_{av} \propto \frac{\Delta\phi}{\Delta t}$
	1721.2 Waveform generated	1512.2 151.2	Bidirectional flow (C) $E \propto P \times \phi_p \times N \times T$
	1721.3 Construction of alternator with rotating D.C. field	1313.1	$F = \frac{P\,N}{120}$
	1721.4 Control of voltage and frequency	1314.4	Excitation
2.2 Three-phase alternators — parts & construction	1722.1 Construction details	1313.1 1611.2	$F = \frac{P\,N}{120}$
	1722.2 Waveforms and phasor diagrams	1511.2	Phase relationships
	1722.3 Advantages of three-phase	1611.1	

Technical Terms	Suggestions for Student Activity	
Alternator Armature Slip rings Bipolar A.C. Sine wave Frequency, hertz Stator Rotor Salient poles Excitation	**SINGLE-PHASE ALTERNATOR (P) (O)** • assemble or connect a simple alternator and study its output waveform. **SINGLE-PHASE ALTERNATOR (E)** • establish the relationships among frequency, terminal voltage, speed and excitation.	Once again the principle o as being of great importanc The output waveform is n appreciate the importance It is noted that the relati abundantly clear as studie alternator progress. Each principle and law. The difference in construc operation should be discus
Three-phase phasor Classes of insulation Non-salient poles	**ALTERNATOR CONNECTIONS (E) (O)** • connect an alternator for single-phase, two-phase, three-phase and six-phase output.	

ggestions for Student Activity	Discussion
E ALTERNATOR (P) (O) r connect a simple alternator and study its output **E ALTERNATOR (E)** e relationships among frequency, terminal voltage, citation.	Once again the principle of electromagnetic induction may be emphasized as being of great importance and broad application. The output waveform is not necessarily a sine wave and students should appreciate the importance of the geometry in the construction. It is noted that the relationships inherent in Faraday's Law will become abundantly clear as studies of the D.C. generator, the transformer and the alternator progress. Each should be seen as a special case of a general principle and law. The difference in construction between alternators for high and low speed operation should be discussed.
CONNECTIONS (E) (O) alternator for single-phase, two-phase, three-phase output.	

DIVISION 1: Theory and Test

UNIT: 1.

Section	Topic	Element	Cros Refere
17.2 Alternators (continued)	**172.3 Three-phase connections**	1723.1 Wye connection; three and four-wire system	1612.1 1612.2
		1723.2 Phase and line voltages	
		1723.3 Delta connection	
		1723.4 Procedures for correct phasing	1513.1 1719.1
	172.4 Losses, temperature rise (O)	1724.1 Copper, iron and mechanical losses	171.7
		1724.2 Factors affecting losses	
		1724.3 Relationship between losses and temperature rise	1717.6 1717.7
		1724.4 Cooling methods	
	172.5 Efficiency, ratings (O)	1725.1 Relationship of input and output power	132.5
		1725.2 Factors governing efficiency	
		1725.3 Factors governing Kva rating and Kw rating	171.8 1116.4
	172.6 Voltage regulation (O)	1726.1 Relationship between no-load and full-load terminal voltage	1714.3 1114.6
		1726.2 Factors affecting voltage regulation	
		1726.3 Effect of degree of excitation on regulation	
	172.7 Synchronization	1727.1 Need for synchronizing of paralleled alternators	1513.1
		1727.2 Procedure	

UNIT: 1.7 A. C. Machines

Topic	Element	Cross-Reference	Fundamentals
.3 Three-phase connections	1723.1 Wye connection; three and four-wire system 1723.2 Phase and line voltages 1723.3 Delta connection 1723.4 Procedures for correct phasing	1612.1 1612.2 1513.1 1719.1	Phase relationships Wye connection line voltage = $\sqrt{3}$ x phase voltage line current = phase current Delta connection line current = $\sqrt{3}$ x phase current line voltage = phase voltage
.4 Losses, temperature rise (O)	1724.1 Copper, iron and mechanical losses 1724.2 Factors affecting losses 1724.3 Relationship between losses and temperature rise 1724.4 Cooling methods	171.7 1717.6 1717.7	Conservation of energy Internal resistance Friction and windage losses Modes of heat transfer Exciter losses
.5 Efficiency, ratings (O)	1725.1 Relationship of input and output power 1725.2 Factors governing efficiency 1725.3 Factors governing Kva rating and Kw rating	132.5 171.8 1116.4	% Efficiency $= \frac{\text{output power}}{\text{input power}} \times 100\%$ $= \frac{(\text{input} - \text{losses})}{\text{input}} \times 100\%$
.6 Voltage regulation (O)	1726.1 Relationship between no-load and full-load terminal voltage 1726.2 Factors affecting voltage regulation 1726.3 Effect of degree of excitation on regulation	1714.3 1114.6	Regulation (C) % voltage regulation $= \frac{(E_{nl} - E_{fl})}{E_{fl}} \times 100\%$
.7 Synchronization	1727.1 Need for synchronizing of paralleled alternators 1727.2 Procedure	1513.1	Synchronization

Technical Terms	Suggestions for Student Activity	D
Three-wire system Four-wire system Phase and line voltages and currents Phasing Phase rotation	**PHASING THREE-PHASE ALTERATORS (E)** • connect a three-phase alternator in wye and delta configurations.	Comprehension of phasing v voltages and currents. Safety precautions should be experimentation.
Copper losses Eddy currents Hysteresis Cooling medium Convection of heat Radiation of heat Conduction of heat Ambient temperature		Very little time need be spent they have been treated thorou The use of hydrogen under p discussed with regard to the a
Efficiency Reactive Volt-amperes Leading and lagging power factor	**ALTERNATOR EFFICIENCY (E) (O)** • determine the efficiency of a given alternator at different loads.	If the efficiency of the drivi ment), the overall efficiency tained experimentally.
Armature reaction Regulation Impedance drop	**ALTERNATOR REGULATION (E)** • determine the effect of the amount and P.F. of the load on alternator voltage regulation.	
Synchronization Synchroscope	**ALTERNATOR SYNCHRONIZATION (E) (O)** • synchronize an alternator with the supply line.	If the synchronizing experim ways: lamps, voltmeter, synch

Suggestions for Student Activity	Discussion
HREE-PHASE ALTERATORS (E) three-phase alternator in wye and delta configurations.	Comprehension of phasing will be gained by vectorial analysis of the voltages and currents. Safety precautions should be adhered to rigorously in this phase of student experimentation.
	Very little time need be spent on losses, efficiency and regulation providing they have been treated thoroughly in transformers and D.C. machines. The use of hydrogen under pressure as a cooling medium could also be discussed with regard to the advantages and dangers.
R EFFICIENCY (E) (O) the efficiency of a given alternator at different loads.	If the efficiency of the driving motor is known (from a previous experiment), the overall efficiency of a given alternator may be readily ascertained experimentally.
R REGULATION (E) the effect of the amount and P.F. of the load on alter- regulation.	
R SYNCHRONIZATION (E) (O) e an alternator with the supply line.	If the synchronizing experiment is performed, it may be done in many ways: lamps, voltmeter, synchroscope, and oscilloscope.

Section	Topic	Element	Cross Referen
17.3 Three-phase induction motors	**173.1 Principle of operation**	1731.1 Rotating magnetic field	11.2 132.1
		1731.2 Induced rotor emf's and rotor currents	1113.3
		1731.3 Magnetic field interaction	1511.2
		1731.4 Reversing rotation	1711.1
	173.2 Construction of squirrel-cage induction motor	1732.1 Stator	1322.1
		1732.2 Rotor	
		1732.3 End shields	
		1732.4 Advantages compared to other motor types	17.4 17.5
		1732.5 Name plate data	1325.3
	173.3 Operating characteristics of squirrel-cage motors	1733.1 Synchronous speed	1731.1
		1733.2 Slip, rotor frequency	
		1733.3 Rotor current, stator current	1324.1
		1733.4 Torque	1731.3
		1733.5 Power factor	152.5
		1733.6 Efficiency	
		1733.7 Operating characteristics	132.5
		1733.8 Applications	

UNIT: 1.7 A. C. Machines

Topic	Element	Cross-Reference	Fundamentals
Principle of operation	1731.1 Rotating magnetic field	11.2 132.1	Rotating fields Electromagnetic induction Synchronous speed $N = \frac{120f}{P}$ Motor principle Phase relationships
	1731.2 Induced rotor emf's and rotor currents	1113.3	
	1731.3 Magnetic field interaction	1511.2	
	1731.4 Reversing rotation	1711.1	
Construction of squirrel-cage induction motor	1732.1 Stator	1322.1	
	1732.2 Rotor	17.4	
	1732.3 End shields	17.5	
	1732.4 Advantages compared to other motor types		
	1732.5 Name plate data	1325.3	
Operating characteristics of squirrel-cage motors	1733.1 Synchronous speed	1731.1	Synchronous (C) $N_s = \frac{120f}{P}$ % Slip $= \frac{(N_s - N_r)}{N_s} \times 100\%$ $T \propto \phi_s I_r \cos \theta_r$ Efficiency $= \frac{P_{out}}{P_{in}}$ Regulation (C) Vectorial representation
	1733.2 Slip, rotor frequency		
	1733.3 Rotor current, stator current	1324.1	
	1733.4 Torque	1731.3	
	1733.5 Power factor	152.5	
	1733.6 Efficiency		
	1733.7 Operating characteristics	132.5	
	1733.8 Applications		

Technical Terms	Suggestions for Student Activity	Di
Rotating magnetic field Synchronous speed Polyphase Induction motor torque	**INDUCTION MOTOR PRINCIPLE (E)** • study the principle of an induction motor. • study the principle of reversing a three-phase motor.	The induction motor is the most It is analogous to a transformer respect to the primary. The principle of the induction m ways; for example, an aluminun under a U-shaped magnet whic
Squirrel-cage winding Stator, rotor, end shields Name plate Frame type Temperature rating	**SQUIRREL CAGE INDUCTION MOTOR (E)** • study the construction of a polyphase S.C. induction motor. • determine the slip torque and speed regulation at several loads. • measure the power factor and efficiency at different loads.	An appreciation of the graphs re very important. The polyphase S.C. induction n torque characteristics as a D.C applications.
Synchronization Slip, rotor torque Power factor Efficiency Speed regulation Iron, copper and friction losses Hysteresis Eddy currents Stray power Regulation Starting torque Breakdown torque		

Suggestions for Student Activity	Discussion
MOTOR PRINCIPLE (E) principle of an induction motor. principle of reversing a three-phase motor.	The induction motor is the most widely used type of a synchronous motor. It is analogous to a transformer with a secondary capable of rotating with respect to the primary. The principle of the induction motor may be demonstrated in many simple ways; for example, an aluminum disc pivoted on a nail point can be placed under a U-shaped magnet which is mounted on the chuck of a drill press.
CAGE INDUCTION MOTOR (E) construction of a polyphase S.C. induction motor. the slip torque and speed regulation at several loads. he power factor and efficiency at different loads.	An appreciation of the graphs representing the operating characteristics is very important. The polyphase S.C. induction motor has essentially the same speed and torque characteristics as a D.C. shunt motor and may be used for similar applications.

Section	Topic	Element
17.3 Three-phase induction motors (continued)	**173.4 Factors affecting speed and regulation**	1734.1 Frequency of supply 1734.2 Number of stator poles 1734.3 Rotor resistance
	173.5 Wound-rotor motor	1735.1 Construction 1735.2 Methods of speed control 1735.3 Advantages and disadvantages compared to squirrel-cage 1735.4 Operating characteristics 1735.5 Applications
17.4 Single-phase motors	**174.1 Survey of single-phase motors**	1741.1 Split-phase I.M. 1741.2 Capacitor-start I.M. 1741.3 Shaded pole 1741.4 Series 1741.5 Repulsion-start I.M. 1741.6 Hysteresis
	174.2 Series (universal motor)	1742.1 Construction and circuitry 1742.2 Operating characteristics 1742.3 Applications

UNIT: 1.7 A. C. Machines

Topic	Element	Cross-Reference	Fundamentals
3.4 Factors affecting speed and regulation	1734.1 Frequency of supply 1734.2 Number of stator poles 1734.3 Rotor resistance	1324.2	$N = \frac{120f}{P}$ Slip
3.5 Wound-rotor motor	1735.1 Construction 1735.2 Methods of speed control 1735.3 Advantages and disadvantages compared to squirrel-cage 1735.4 Operating characteristics 1735.5 Applications	173.2 173.3	Rotor resistance and speed Torque
4.1 Survey of single-phase motors	1741.1 Split-phase I.M. 1741.2 Capacitor-start I.M. 1741.3 Shaded pole 1741.4 Series 1741.5 Repulsion-start I.M. 1741.6 Hysteresis		
4.2 Series (universal motor)	1742.1 Construction and circuitry 1742.2 Operating characteristics 1742.3 Applications	132.2 132.4	Motor principle

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Technical Terms	Suggestions for Student Activity	
Synchronous speed Rotor speed	**FACTORS AFFECTING MOTOR SPEED (E)** • show the effect of changing the stator poles on the motor speed. • show the effect of varying the frequency of the supply on the motor speed.	If wound-rotor motors demonstration, and pr by the students. The operating charact shunt motor in which circuit.
Wound-rotor induction motor Slip rings Speed regulation Starting torque Acceleration Adjustable speed	**WOUND-ROTOR MOTOR (E)** • study the starting and operating characteristics of the wound-rotor induction motor.	
Split-phase motor Capacitor-start motor Shaded pole motor Series, universal motor Repulsion-start motor Hysteresis motor		The many types of si not permit a thoroug induction motor in its
Universal motor Series motor	**SERIES MOTORS (A)** • study the construction of universal single-phase motors. • study speed-voltage and speed load-characteristics.	

ggestions for Student Activity	Discussion
FFECTING MOTOR SPEED (E) ffect of changing the stator poles on the motor speed. ffect of varying the frequency of the supply on the	If wound-rotor motors are available, concatenation makes an interesting demonstration, and provokes discussion. It should not be studied formally by the students. The operating characteristics of the wound-rotor motor are similar to a shunt motor in which series resistance has been added to the armature circuit.
OR MOTOR (E) starting and operating characteristics of the wound- n motor.	
	The many types of single-phase motors may be discussed, but time does not permit a thorough study of each. The operation of the single-phase induction motor in its running condition should not be attempted in depth.
ORS (A) onstruction of universal single-phase motors. d-voltage and speed load-characteristics.	

Section	Topic	Element
17.4 Single-phase motors (continued)	**174.3 Split-phase and capacitor-start induction motors**	1743.1 Construction and circuitry 1743.2 Starting principle — vector diagrams 1743.3 Operating characteristics 1743.4 Reversing rotation 1743.5 Disadvantages compared to polyphase I.M. 1743.6 Applications
	174.4 Shaded-pole	1744.1 Construction and circuitry 1744.2 Shading coil effect 1744.3 Operating characteristics 1744.4 Applications
	174.5 Repulsion-induction (O)	1745.1 Construction and circuitry 1745.2 Starting principle 1745.3 Operating characteristics 1745.4 Reversing rotation 1745.5 Applications

UNIT: 1.7 A. C. Machines

Topic	Element	Cross-Reference	Fundamentals
3 Split-phase and capacitor-start induction motors	1743.1 Construction and circuitry		Centrifugal force Motor principle Phase relationships Vectorial representation
	1743.2 Starting principle — vector diagrams	151.3 154.1	
	1743.3 Operating characteristics	1536.1	
	1743.4 Reversing rotation	1521.5	
	1743.5 Disadvantages compared to polyphase I.M.	173.1 173.3	
	1743.6 Applications	152.3	
Shaded-pole	1744.1 Construction and circuitry	173.1	Shading coil principle Lenz's Law
	1744.2 Shading coil effect	151.3	
	1744.3 Operating characteristics		
	1744.4 Applications		
Repulsion-induction (O)	1745.1 Construction and circuitry	1313.1	Motor principle Faraday's Law
	1745.2 Starting principle		
	1745.3 Operating characteristics	173.1 132.1	
	1745.4 Reversing rotation		
	1745.5 Applications		

Technical Terms	Suggestions for Student Activity	
Centrifugal switch Synchronous speed Starting capacitor Starting or auxiliary winding Running or main winding	**SINGLE-PHASE MOTORS (A)** • Examine the construction of split-phase and capacitor-start induction motors. • Compare, using graphs, their operating characteristics such as starting current and torque, maximum torque and speed-load curves.	Much time could be spent split-phase and capacitor-s will be governed by the tim
Shading coil	**SHADED-POLE MOTOR (A)** • Study the construction operation and application.	The hysteresis motor has b that it requires attention, h At the conclusion of this s able to select intelligently
Short circuiting necklace Shorting disc Brush lifting mechanism	**REPULSION-INDUCTION MOTOR (E)** • observe the starting action of a repulsion-induction motor. • reverse an R-I motor.	

Suggestions for Student Activity	Discussion
IASE MOTORS (A) the construction of split-phase and capacitor-start in- otors. e, using graphs, their operating characteristics such as urrent and torque, maximum torque and speed-load	Much time could be spent on the details of construction and operation of split-phase and capacitor-start motors. However the depth of treatment will be governed by the time available.
OLE MOTOR (A) e construction operation and application.	The hysteresis motor has been omitted from this study. If the teacher feels that it requires attention, he may introduce it. At the conclusion of this study on motors, it is hoped that the pupil will be able to select intelligently a motor for a given application.
N-INDUCTION MOTOR (E) the starting action of a repulsion-induction motor. an R-I motor.	

Section	Topic	Element
17.5 Synchronous motors (O)	**175.1 Construction**	1751.1 Stator 1751.2 Rotor, slip rings, brushes 1751.3 End shields
	175.2 Principle of operation	1752.1 Rotating magnetic field 1752.2 Magnetized rotor 1752.3 "Locking-in" 1752.4 Starting method
	175.3 Operating characteristics	1753.1 Effect of adding load 1753.2 Power factor correction 1753.3 Curves relating power factor and I_f 1753.4 Applications

UNIT: 1.7 A. C. Machines

Topic	Element	Cross-Reference	Fundamentals
Construction	1751.1 Stator 1751.2 Rotor, slip rings, brushes 1751.3 End shields	1722.1	Magnetization
Principle of operation	1752.1 Rotating magnetic field 1752.2 Magnetized rotor 1752.3 "Locking-in" 1752.4 Starting method	1731.1 172.7	Synchronous motor principle Synchronization (C) $\text{Slip} = \frac{120f}{P}$
Operating characteristics	1753.1 Effect of adding load 1753.2 Power factor correction 1753.3 Curves relating power factor and I_f 1753.4 Applications	152.5 1545.3	Phase relationships Power factor adjustment

Technical Terms	Suggestions for Student Activity
Synchronous motor Amortisseur, damping winding	**SYNCHRONOUS MOTOR (E)** • Verify constant speed characteristics of the sychronous motor, from no load to full load. • demonstrate power factor correction using a synchronous motor.
"Hunting" Power factor Torque: angle, pull-out, pull-in Synchronous capacitors	

Suggestions for Student Activity	Discussion
NOUS MOTOR (E) onstant speed characteristics of the sychronous motor, d to full load. rate power factor correction using a synchronous	

DIVISION 2: Electronics

UNIT: 2.1 Standard Electron

Section	Topic	Element	Cr Refer
21.1 Magnetic relays	**211.1 Electro-mechanical features**	2111.1 Elementary principle	11.
		2111.2 Construction & functions of parts	
		2111.3 Basic A.C. & D.C. features	174.
	211.2 Commercial types	2112.1 Telephone	
		2112.2 Hermetically sealed	
		2112.3 Time delay	
		2112.4 Stepping relays (O)	153.
		2112.5 Other (O)	
	211.3 Typical applications	2113.1 Contact arrangements	2424.
		2113.2 Schematic representation	242.
		2113.3 Some applications in electronics	351. 362.
21.2 Resistors	**212.1 Types of resistors**	2121.1 Fixed	1114. 111. 231. 231. 232. 232. 2.4, 2
		2121.2 Variable	2.4, 2 1314.

UNIT: 2.1 Standard Electronic Components

Topic	Element	Cross-Reference	Fundamentals
Electro-mechanical features	2111.1 Elementary principle	11.2	Magnetic attraction
	2111.2 Construction & functions of parts		Bistable mechanisms Switching
	2111.3 Basic A.C. & D.C. features	174.3	
Commercial types	2112.1 Telephone		Shading coil principle
	2112.2 Hermetically sealed		
	2112.3 Time delay		
	2112.4 Stepping relays (O)	153.4	
	2112.5 Other (O)		
Typical applications	2113.1 Contact arrangements	2424.1	Boolean algebra
	2113.2 Schematic representation	242.1	
	2113.3 Some applications in electronics	351.4 362.1	
Types of resistors	2121.1 Fixed	1114.2 111.5 231.1, 231.4 232.1, 232.3 2.4, 2.5	$R = \frac{\text{Resistivity x length}}{\text{Area of cross-section}}$ $P = EI$ Resistance heating
	2121.2 Variable	2.4, 2.5 1314.4	Proportionality (C)

Technical Terms	Suggestions for Student Activity	Dis
Frame, armature, coil, return spring Current: pull-in, drop-out Differential current, chatter, shading coil, air gap	**MAGNETIC RELAY TEST (E) (O)** • examine the construction & test for the operating characteristics of typical relays.	Besides being a good example also analagous to bistable ele certain logic functions and it p design of complex switching design of such circuitry.
Hermetically sealed		
Composition Wirewound Precision Heat dissipation Thermal instability Carbon element, taper Potentiometer Rheostat Trimming pot	**COLOUR CODE (E)** Identify resistors: • by type • by colour code • by power rating	Other types of resistors may b importance.

Suggestions for Student Activity	Discussion
C RELAY TEST (E) (O) e the construction & test for the operating characteristics relays.	Besides being a good example of applied electro-magnetism, the relay is also analagous to bistable electronic circuits. As such, it can perform certain logic functions and it provides many interesting possibilities for design of complex switching circuits. Boolean algebra is used in the design of such circuitry.
CODE (E) esistors: e ur code er rating	Other types of resistors may be introduced in proportion to their increasing importance.

DIVISION 2: Electronics

UNIT: 2.1 Standard Electr

Section	Topic	Element	Cr Refe
21.3 Inductors	**213.1 Types of inductors**	2131.1 Air-core	15
		2131.2 Iron-core	11
		2131.3 Variable	2321
21.4 Capacitors	**214.1 Types of capacitors**	2141.1 Fixed	15 2321 2321 2323 2324
		2141.2 Variable	2321 2223
21.5 Transformers	**215.1 Iron-core**	2151.1 Electronic power transformers	17 231
		2151.2 Audio transformers	232 111
	215.2 Air-core	2152.1 Antenna coils	11
		2152.2 R.F. transformers	152 232
		2152.3 I.F. transformers	154 154
	215.3 Ferrite-core	2153.1 Rod antennas	17
		2153.2 R.F. transformers	11 154
		2153.3 I.F. transformers	232 154

UNIT: 2.1 Standard Electronic Components

Topic	Element	Cross-Reference	Fundamentals
Types of inductors	2131.1 Air-core 2131.2 Iron-core 2131.3 Variable	15.2 11.2 2321.8	Inductance Lenz's Law Faraday's Law
Types of capacitors	2141.1 Fixed 2141.2 Variable	15.3 2321.3 2321.5 2323.3 2324.1 2321.5 2223.4	Capacitance $Q = CE$ Law of Electrical Charge
Iron-core	2151.1 Electronic power transformers 2151.2 Audio transformers	17.1 231.1 232.2 1114.6	Mutual induction Faraday's Law Lenz's Law Impedance matching $Z_p = \left(\frac{T_p}{T_s}\right)^2 Z_s$
Air-core	2152.1 Antenna coils 2152.2 R.F. transformers 2152.3 I.F. transformers	11.2 152.4 232.4 154.2 154.4	$Q = \frac{X_L}{R_s}$ Bandwidth $= \frac{f_o}{Q}$ Selectivity (C)
Ferrite-core	2153.1 Rod antennas 2153.2 R.F. transformers 2153.3 I.F. transformers	17.1 11.2 154.2 232.4 154.4	Magnetic properties

Technical Terms	Suggestions for Student Activity	Disc
Self-inductance, inductor, choke Henry, Millihenry, microhenry Figure of merit Distributed capacitance Ferrite	**INDUCTANCE MEASUREMENT (E) (O)** • measure the inductance of several inductors (using a bridge or Q-meter).	The basics of inductors, capacito Division 1. The new material sug covers the differences in theory, components are used in electronics
Capacitance, capacitor Farad Dielectric: paper, mica, mylar, ceramic, oil-filled, electrolytic Drift Tuning capacitor Trimmer, padder	**CAPACITOR COLOUR CODES (E)** • identify capacitors according to colour codes. **CAPACITANCE MEASUREMENT (E)** • measure the capacitance of various capacitors (using a bridge or capacitor meter).	
Power transformer, Audio transformer Line isolation Electrostatic shielding, Faraday shield Volt-ampere rating Volts-per-turn Impedance ratio Transformers: matching, driving and output	**WINDING IDENTIFICATION (E)** • identify transformer winding by colour code. • identify windings by ohmmeter tests. **IMPEDANCE MATCHING (E)** • use a transformer as an impedance matching device.	
Figure of merit Resonance Bandwidth, selectivity, half-power points Critical coupling . Skin effect		
Hysteresis Eddy currents Efficiency		

uggestions for Student Activity	Discussion
E MEASUREMENT (E) (O) he inductance of several inductors (using a bridge or	The basics of inductors, capacitors and transformers are listed under Division 1. The new material suggested for sections 21.3, 21.4, and 21.5 covers the differences in theory, construction, and applications as these components are used in electronics.
COLOUR CODES (E) pacitors according to colour codes. **CE MEASUREMENT (E)** he capacitance of various capacitors (using a bridge meter).	
ENTIFICATION (E) nsformer winding by colour code. ndings by ohmmeter tests. **MATCHING (E)** sformer as an impedance matching device.	

UNIT: 2.2 El

Section	Topic	Element	Cross Referen
22.1 Vacuum and gaseous tubes	**221.1 Vacuum diodes**	2211.1 Electron emission	111.1
		2211.2 Construction	23.1
		2211.3 Theory of operation	111.2
		2211.4 Characteristic curve (O)	
	221.2 Vacuum triodes	2212.1 Construction and theory of operation	111.2 232.1 232.2 232.4
		2212.2 Characteristic curves and tube parameters	1114.6 232.5 232.6 232.7
	221.3 Vacuum pentodes	2213.1 Construction and theory of operation	111.2 1114.6 232.1 232.2 232.4 232.5 232.6 232.7

UNIT: 2.2 Electron Devices

Topic	Element	Cross-Reference	Fundamentals
221.1 Vacuum diodes	2211.1 Electron emission	111.1	Conversion of energy (thermionic emission)
	2211.2 Construction	23.1	
	2211.3 Theory of operation	111.2	Edison effect Law of Electrical Charges Coulomb's Law: $F \propto \frac{q_1 q_2}{d^2}$ Unidirectional flow (C) Rectification
	2211.4 Characteristic curve (O)		
221.2 Vacuum triodes	2212.1 Construction and theory of operation	111.2 232.1 232.2 232.4	Edison effect Law of Electrical Charges Coulomb's Law Amplification (C)
	2212.2 Characteristic curves and tube parameters	1114.6 232.5 232.6 232.7	$\mu = \frac{\Delta E_b}{\Delta E_c}$ $R_p = \frac{\Delta E_b}{\Delta I_b}$ $g_m = \frac{\Delta I_b}{\Delta E_c}$ Graphical representation of variables
221.3 Vacuum pentodes	2213.1 Construction and theory of operation	111.2 1114.6 232.1 232.2 232.4 232.5 232.6 232.7	Conservation of energy (secondary emission) Negative resistance (C)

Technicai Terms	Suggestions for Student Activity	
Diode Thermionic emission Directly heated cathode Indirectly heated cathode Anode, plate Filament, heater Space charge Saturation current Rectification, rectifier	**SIMPLE HALF-WAVE RECTIFIER (E)** • study the behaviour of a vacuum diode as a simple half-wave rectifier.	The order of listing does not i semi-conductors. Indeed, it is with semi-conductors. The relative amount of time conductors is a matter of de time, one would expect incre
Triode, triode symbol Control grid Grid bias Current "cut-off" Amplification factor Plate resistance Transconductance Delta = small change in	**CALCULATION OF CONSTANTS (X)** • determine graphically tube constants from given characteristic curves. **PLATE AND GRID CURVES (X)** • plot plate and grid curves by transfer of plate characteristics to transconductance characteristic curves.	
Pentode, tetrode Screen grid, suppressor grid Secondary emission Negative resistance Beam-power pentode	**DETERMINATION OF PENTODE PLATE CHARACTERISTICS (E)** • measure and plot the plate characteristic curves of a typical pentode.	

Suggestions for Student Activity	Discussion
ALF-WAVE RECTIFIER (E) e behaviour of a vacuum diode as a simple half-wave	The order of listing does not imply that vacuum tubes need be taught before semi-conductors. Indeed, it is likely that many teachers will wish to begin with semi-conductors. The relative amount of time spent on vacuum devices compared to semi-conductors is a matter of decision for the teacher. With the passage of time, one would expect increasing emphasis on the semi-conductors.
TION OF CONSTANTS (X) ne graphically tube constants from given characteristic **D GRID CURVES (X)** e and grid curves by transfer of plate characteristics to ctance characteristic curves.	
ATION OF PENTODE PLATE CHARACTERISTICS (E) e and plot the plate characteristic curves of a typical	

DIVISION 2: Electronics

UNIT: 2.2

Section	Topic	Element	Cro Refer
22.1 Vacuum and gaseous tubes (continued)	**221.4 Multi-purpose vacuum tubes**	2214.1 Various types: double-diode triode, double triode, pentagrid converter, double diode	231.1 243.2 241.2
	221.5 Light-sensitive tubes	2215.1 The photoemissive tubes 2215.2 The photomultiplier (O)	221.3
	221.6 The cathode ray tube	2216.1 Construction	111.1
		2216.2 Theory of operation	1112.3
		2216.3 Applications	112.2 25.3
		2216.4 Safety precautions	2451.3
	221.7 Radiation detectors (O)	2217.1 Construction and operation of scintillation counter — the Geiger-Muller tube	111.
	221.8 Readout devices (O)	2218.1 Construction and operation of the "Nixie" tube; other gas glow-indicators	
22.2 Semi-conductor devices	**222.1 Basic physics of semiconductor materials**	2221.1 Semi-conductor material	111.1
		2221.2 Doping	1115.1

UNIT: 2.2 Electron Devices

Topic	Element	Cross-Reference	Fundamentals
1.4 Multi-purpose vacuum tubes	2214.1 Various types: double-diode triode, double triode, pentagrid converter, double diode	231.1 243.2 241.2	
1.5 Light-sensitive tubes	2215.1 The photoemissive tubes 2215.2 The photomultiplier (O)	221.3	Photoemission Spectral response Secondary emission Ionization
1.6 The cathode ray tube	2216.1 Construction 2216.2 Theory of operation 2216.3 Applications 2216.4 Safety precautions	111.1 1112.3 112.2 25.3 2451.3	Electron beam formation and deflection: electrostatic and magnetic Luminescence
1.7 Radiation detectors (O)	2217.1 Construction and operation of scintillation counter — the Geiger-Muller tube	111.1	Radiation
1.8 Readout devices (O)	2218.1 Construction and operation of the "Nixie" tube; other gas glow-indicators		Ionization
2.1 Basic physics of semiconductor materials	2221.1 Semi-conductor material 2221.2 Doping	111.1 1115.1	Molecular structure of crystalline materials Effect of impurities on electrical properties

Technical Terms	Suggestions for Student Activity	Disc
Converter, pentagrid Mixer	**COMPARISON STUDY OF TUBES (A)** • compare the physical and electrical features of several diodes, triodes and pentodes.	
Photoemissive cell Photomultiplier Ionization		If time permits, experiments with l tectors should be performed; ho should be given.
Electron gun Accelerating and focussing anodes Luminescence, persistence Implosion	**ELECTRON BEAM DEFLECTION (E)** • examine the construction of an electron gun. • study qualitatively electrostatic and magnetic deflection of the electron beam.	The many different applications of that the student has a firm grasp of
Radiation Scintillation counter Geiger-Muller tube Radioactivity		
Nixie Readout		
Semi-conductor Crystal structure Valence electrons Covalent bonds Doping, P-type, N-type Holes		Motion pictures provide an effici physics of semi-conductors and se

Suggestions for Student Activity	Discussion
ON STUDY OF TUBES (A) the physical and electrical features of several diodes, pentodes.	
	If time permits, experiments with light-sensitive devices and radiation detectors should be performed; however, demonstration of these devices should be given.
BEAM DEFLECTION (E) the construction of an electron gun. alitatively electrostatic and magnetic deflection of the am.	The many different applications of the cathode ray tube make it desirable that the student has a firm grasp of its operating fundamentals.
	Motion pictures provide an efficient means of communicating the basic physics of semi-conductors and semi-conductor devices.

Section	Topic	Element	Cro Refer
22.2 Semi-conductor devices (continued)	**222.2 Semi-conductor diodes**	2222.1 P-N junction: construction and electrical properties 2222.2 Characteristics curve 2222.3 Special diodes: zener, tunnel, photo	221.1 23.1 231.3 221.3 1113.5 233.8 242.1
	222.3 Transistors	2223.1 Basic transistor types: PNP and NPN 2223.2 Theory of operation 2223.3 Transistor parameters 2223.4 Power types 2223.5 Comparison of the transistor and the vacuum tube 2223.6 S.C.R.	111.1 111.5 2212.2 232.3 232.4 232.5 232.6 232.7 1411.4 232.8
	222.4 Other non-linear devices (O)	2224.1 Varistor, varactor, thermistor, phototransistor, unijunction transistor 2224.2 Field effect transistors: FET, MOSFET	1113.5 1115.2

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UNIT: 2.2 Electron Devices

Topic	Element	Cross-Reference	Fundamentals
222.2 Semi-conductor diodes	2222.1 P-N junction: construction and electrical properties 2222.2 Characteristics curve 2222.3 Special diodes: zener, tunnel, photo	221.1 23 1 231.3 221.3 1113.5 233.8 242.1	Unidirectional flow (C) Biasing Variation of conductivity with light Negative resistance (C)
222.3 Transistors	2223.1 Basic transistor types: PNP and NPN 2223.2 Theory of operation 2223.3 Transistor parameters 2223.4 Power types 2223.5 Comparison of the transistor and the vacuum tube 2223.6 S.C.R.	111.1 111.5 2212.2 232.3 232.4 232.5 232.6 232.7 1411.4 232.8	Amplification (C) $\alpha = \frac{\Delta I_c}{\Delta I_e}$ $\beta = \frac{\Delta I_c}{\Delta I_b}$ Property changes due to environmental variation
222.4 Other non-linear devices (O)	2224.1 Varistor, varactor, thermistor, phototransistor, unijunction transistor 2224.2 Field effect transistors: FET, MOSFET	1113.5 1115.2	Nonlinearity (C) Negative resistance (C)

Technical Terms	Suggestions for Student Activity	
Junction Barrier voltage Forward bias, reverse bias Majority carriers, minority carriers Injection Leakage current, avalanche Zener effect Tunnel diode Photodiode Photovoltaic Photoconductive	**P-N JUNCTION CHARACTERISTICS (E)** • measure and plot the characteristic curves of a semi-conductor P-N diode.	
PNP, NPN transistors Emitter, base, collector Bias current Parameter Collector dissipation Heat sink Silicon controlled rectifier Thyristor Triac Phototransistor	**TRANSISTOR CHARACTERISTICS (E)** • plot a family of collector curves. • calculate the parameters from the curves. **S.C.R. CHARACTERISTICS (E)** • determine and plot the characteristics of a typical S.C.R.	"H" parameters should be int Thyratrons should be mentic their relative obsolescence.
Varistor Varactor Thermistor; temperature coefficient Photoconductive and photovoltaic Field effect transistors	**NONLINEAR DEVICES (E)** • illustrate the operation of one or more of these devices: thermistor, photovoltaic, cell and varistor.	Although little time is availab should keep abreast of appli this area as developments wa

Suggestions for Student Activity	Discussion
CTION CHARACTERISTICS (E) re and plot the characteristic curves of a semi-conductor e.	
TOR CHARACTERISTICS (E) family of collector curves. ate the parameters from the curves. **HARACTERISTICS (E)** nine and plot the characteristics of a typical S.C.R.	"H" parameters should be introduced as equivalents to α and β. Thyratrons should be mentioned but need not be emphasized because of their relative obsolescence.
EAR DEVICES (E) ate the operation of one or more of these devices: or, photovoltaic, cell and varistor.	Although little time is available for the study of these devices, the teacher should keep abreast of applications and attempt to evolve his course in this area as developments warrant.

DIVISION 2: Electronics

UNIT: 2.3 Basic Ele

Section	Topic	Element	Cro Refer
23.1 Circuits using diodes	**231.1 Power supplies**	2311.1 Half-wave	222. 221. 1522. 153. 2. 2. 123. 17. 1315. 1412. 1532, 162.
		2311.2 Transformer type	
		2311.3 Cascade voltage doubler	
		2311.4 Bridge type	
	231.2 Clippers, clamps, limiters (O)	2312.1 Diode clipper	221. 222.
		2312.2 Diode clamp	
		2312.3 Diode limiter	

UNIT: 2.3 Basic Electronic Circuits

Topic	Element	Cross-Reference	Fundamentals
31.1 Power supplies	2311.1 Half-wave 2311.2 Transformer type 2311.3 Cascade voltage doubler 2311.4 Bridge type	222.2 221.1 1522.3 153.4 2.4 2.5 123.1 17.1 1315.2 1412.6 1532,4 162.1	Unidirectional flow Energy storage Filter Time constants Regulation
31.2 Clippers, clamps, limiters (O)	2312.1 Diode clipper 2312.2 Diode clamp 2312.3 Diode limiter	221.1 222.2	Polarity sensing Biasing Amplitude limiting

Technical Terms	Suggestions for Student Activity	Dis
Filter capacitor and choke Swinging choke Half-wave, full-wave Brute force filter Pi filters Choke input and capacitor input Ripple Regulation P.I.V. and P.R.V. Bleeder Power transformer	**TYPICAL POWER SUPPLIES (E) (O)** • make measurements on typical power supplies with respect to waveforms, voltages and regulations.	Comparison between rectifier ci presented as demonstrations.
Clipper Pulses: positive, and negative going Bias voltage Clamp Shunt rectifier Voltage excursion Amplitude limiting Biased limiter	**CLIPPING (E) (O)** • examine clipping action. **CLAMPING (E)** • observe clamp action in a voltage doubler.	

Suggestions for Student Activity	Discussion
	Comparison between rectifier circuits and between filter circuits can be presented as demonstrations.
POWER SUPPLIES (E) (O) measurements on typical power supplies with respect to ns, voltages and regulations.	
(E) (O) ne clipping action. **IG (E)** e clamp action in a voltage doubler.	

Section	Topic	Element	Cros Refere
23.1 Circuits using diodes (continued)	**231.3 Voltage regulation**	2313.1 Zener diode	2222.3
		2313.2 Design considerations of simple zener regulating circuit	242.3
	231.4 Demodulating circuits	2314.1 Diode AM detector	2324.2 2431.1 243.2
		2314.2 Foster-Seeley detector (O)	2324.4 1511.3 243.3
		2314.3 Ratio detector (O)	2324.4 243.3

UNIT: 2.3 Basic Electronic Circuits

Topic	Element	Cross-Reference	Fundamentals
231.3 Voltage regulation	2313.1 Zener diode	2222.3	The zener effect
	2313.2 Design considerations of simple zener regulating circuit	242.3	
231.4 Demodulating circuits	2314.1 Diode AM detector	2324.2 2431.1 243.2	Rectification Modulation Demodulation Filters
	2314.2 Foster-Seeley detector (O)	2324.4 1511.3 243.3	
	2314.3 Ratio detector (O)	2324.4 243.3	

Technical Terms	Suggestions for Student Activity	
Zener action Avalanche, thermal runaway	**VOLTAGE REGULATION (E)** • test a zener regulating circuit.	Gas diodes should be ment relative obsolescence.
Nonlinearity Rectifier Modulation Demodulation Carrier AM	**SIMPLE DIODE DETECTION (E)** • use of simple tuned circuit and semiconductor to detect AM signals. **CONVENTIONAL DETECTOR CIRCUIT (E)** • examine waveforms and voltages in the conventional AM detector circuit.	The concept of modulation i confined merely to communi vides the most familiar and h The teacher may be able to co demodulation must be accom Frequency modulation and de be appreciated by the more ca
Bandwidth Phase angle Vector Phasor Frequency modulation	**ADJUSTMENT OF FM DETECTORS (E) (O)** • examine the operation of an FM detector and adjust the tuned circuits observing the response curve.	

Suggestions for Student Activity	Discussion
TAGE REGULATION (E) st a zener regulating circuit.	Gas diodes should be mentioned but not emphasized because of their relative obsolescence.
LE DIODE DETECTION (E) e of simple tuned circuit and semiconductor to detect AM als. **VENTIONAL DETECTOR CIRCUIT (E)** amine waveforms and voltages in the conventional AM de- r circuit. **USTMENT OF FM DETECTORS (E) (O)** amine the operation of an FM detector and adjust the tuned its observing the response curve.	The concept of modulation is an important one in electronics and is not confined merely to communications applications, although the latter provides the most familiar and hence probably the most motivating examples. The teacher may be able to convey to the student that both modulation and demodulation must be accomplished by the use of nonlinear elements. Frequency modulation and demodulation are more difficult topics but can be appreciated by the more capable students.

Section	Topic	Element	Cros Refere
23.2 Circuits using amplifying devices	**232.1 Vacuum-tube voltage amplifiers**	2321.1 Amplifying action of the grounded cathode circuit	221.2 2323.1 2.4,2.5
		2321.2 Graphical analysis: load lines, classes of operation	2323.2
		2321.3 Methods of biasing	153.4 2323.3
		2321.4 Equivalent circuit for an amplifier	
		2321.5 Frequency response of R-C amplifiers	153.4
		2321.6 Cathode follower	2323.1
		2321.7 D.C. amplifiers	242.3
		2321.8 Inductance loaded	152.4
		2321.9 Grounded grid amplifier	2323.1

UNIT: 2.3 Basic Electronic Circuits

Topic	Element	Cross-Reference	Fundamentals
232.1 Vacuum-tube voltage amplifiers	2321.1 Amplifying action of the grounded cathode circuit	221.2 2323.1 2.4,2.5	Amplification
	2321.2 Graphical analysis: load lines, classes of operation	2323.2	Graphical representation of characteristics Fidelity: distortion Operating point
	2321.3 Methods of biasing	153.4 2323.3	Biasing
	2321.4 Equivalent circuit for an amplifier		Equivalent circuits gain $= \frac{\mu R_L}{r_p + R_L}$
	2321.5 Frequency response of R-C amplifiers	153.4	Frequency response
	2321.6 Cathode follower	2323.1	Impedance matching Feedback (C)
	2321.7 D.C. amplifiers	242.3	
	2321.8 Inductance loaded	152.4	
	2321.9 Grounded grid amplifier	2323.1	

Technical Terms	Suggestions for Student Activity	
Voltage amplifier Plate load Supply voltage Bias Signal voltage Phase inversion Characteristic curves	**THE TRIODE AMPLIFIER (E)** • analysis of D.C. and A.C. conditions in an operating amplifier circuit. • measuring stage gain.	Some of the elements listed amplifier circuits.
Load line, operating point Input and output signals Phase inversion Class of operation (A, B, C etc.) Distortion, cut-off	**DESIGN AND TEST OF A SIMPLE AMPLIFIER (E)** • use graphical analysis to design a simple triode amplifier and to set up the circuit to confirm the design practically.	Graphical analysis and desi tronic theory. The student sh
Fixed bias, self bias Cathode, grid leak bias Contact bias Equivalent circuit		The equivalent circuit for Equivalent circuits for trans only be attempted if the tea
Frequency response Time constant	**AMPLIFIER FREQUENCY RESPONSE (E)** • plot the frequency response of a single stage R-C coupled amplifier.	
Degeneration, feedback Phase splitter Impedance matching	**CATHODE FOLLOWER (E)** • confirm the theory of operation.	
D.C. amplification "Elliptical" load line		Inductance loading, while n former-loaded power amplifie may go above supply voltage

Suggestions for Student Activity	Discussion
E AMPLIFIER (E) of D.C. and A.C. conditions in an operating amplifier ng stage gain.	Some of the elements listed here are equally applicable to semiconductor amplifier circuits.
ND TEST OF A SIMPLE AMPLIFIER (E) hical analysis to design a simple triode amplifier and to ircuit to confirm the design practically.	Graphical analysis and design are powerful aids to understanding electronic theory. The student should appreciate its importance.
	The equivalent circuit for a vacuum tube amplifier is a useful concept. Equivalent circuits for transistors are somewhat more difficult and should only be attempted if the teacher is convinced of their value to the student.
FREQUENCY RESPONSE (E) frequency response of a single stage R-C coupled	
FOLLOWER (E) he theory of operation.	
	Inductance loading, while not common, is a good preparation for transformer-loaded power amplifiers. Note that under signal conditions the plate may go above supply voltage.

Section	Topic	Element	Cros Refere
23.2 Circuits using amplifying devices (continued)	**232.2 Vacuum tube power amplifiers**	2322.1 Comparison between voltage and power amplification 2322.2 Transformer loaded 2322.3 Push-pull power Stage: configuration and advantages	215.1 111.6 17.1 241.2 241.3
	232.3 Solid state amplifiers	2323.1 Basic configurations and their amplifying actions 2323.2 Graphical analysis: load lines, classes of operation 2323.3 Methods of biasing	2323.1 2323.6 2323.9 2.4,2.5 2321.2 2321.3

UNIT: 2.3 Basic Electronic Circuits

Topic	Element	Cross-Reference	Fundamentals
2.2 Vacuum tube power amplifiers	2322.1 Comparison between voltage and power amplification	215.1 111.6	$N_{dB} = 10 \log \frac{P_{out}}{P_{in}}$
	2322.2 Transformer loaded	17.1	
	2322.3 Push-pull power Stage: configuration and advantages	241.2 241.3	$\frac{Z_p}{Z_s} = \left(\frac{T_p}{T_s}\right)^2$ Push-pull action Distortion
.3 Solid state amplifiers	2323.1 Basic configurations and their amplifying actions	2323.1 2323.6	Amplification
	2323.2 Graphical analysis: load lines, classes of operation	2323.9 2.4,2.5	Graphical representation
	2323.3 Methods of biasing	2321.2 2321.3	Biasing Stability

Technical Terms	Suggestions for Student Activity	Disc
Power amplifier, tube ratings Plate and screen dissipation Decibels Single-ended, push-pull Impedance matching Inductance loading Optimum loading Distortion: harmonic intermodulation	**POWER AMPLIFIER (E)** • measure the power gain of a power amplifier. • single ended stage • push-pull stage.	
Common-base, emitter collector Input/output Impedance Characteristic curves Load line, operating point Class A, B etc. Fixed bias, self bias Bias stabilization Thermal stability and runaway	**TRANSISTOR AMPLIFIER CIRCUITS (E)** • measure the amplifying of transistor amplifiers in the three basic configurations. **AMPLIFIER DESIGN (E)** • design graphically a typical amplifier circuit. • test the design practically. **BIAS CIRCUIT DESIGN (E)** • design and test a typical bias circuit that provides stabilization.	Equivalent circuits for transistors tubes. Their introduction is not rec See "discussion" on graphical ana

gestions for Student Activity	Discussion
IFIER (E) power gain of a power amplifier. l stage ge.	
AMPLIFIER CIRCUITS (E) e amplifying of transistor amplifiers in the three tions. **SIGN (E)** ically a typical amplifier circuit. gn practically. **DESIGN (E)** est a typical bias circuit that provides stabilization.	Equivalent circuits for transistors are more difficult than those for vacuum tubes. Their introduction is not recommended. See "discussion" on graphical analysis — 2321.2.

Section	Topic	Element	C Re
23.2 Circuits using amplifying devices (continued)	**232.3 Solid state amplifiers**	2323.4 Methods of coupling: R-C, transformer, direct	2.4 24
		2323.5 Phase inversion and complementary symmetry	24 11
		2323.6 Power amplifier	2.4
	232.4 R.F. amplifiers	2324.1 Application of resonant circuits	15 15
		2324.2 Nature of AM signals	24 2
		2324.3 AM r.f. and i.f. circuits (O)	215 215
		2324.4 Nature of FM signals (O)	23 23

UNIT: 2.3 Basic Electronic Circuits

Topic	Element	Cross-Reference	Fundamentals
3 Solid state amplifiers	2323.4 Methods of coupling: R-C, transformer, direct 2323.5 Phase inversion and complementary symmetry 2323.6 Power amplifier	2.4,2.5 241.2 241.3 111.6 2.4,2.5	Frequency response Complementary symmetry Decibel Distortion $db = 10 \log \frac{\text{power out}}{\text{power in}}$
4 R.F. amplifiers	2324.1 Application of resonant circuits 2324.2 Nature of AM signals 2324.3 AM r.f. and i.f. circuits (O) 2324.4 Nature of FM signals (O)	154.2 154.4 243.1 231.4 2152.2 2152.3 2314.2 2314.3	$f_0 = \frac{1}{2\pi\sqrt{LC}}$ $Q = \frac{X_L}{R}$ $B.W. = \frac{f_0}{Q}$ Selectivity Modulation Modulation

Technical Terms	Suggestions for Student Activity	Disc
Input loading, mismatch Diode bias-stabilization Cross-over distortion Frequency response		
Paraphase amplifier Phase splitter Complementary symmetry emitter follower	**PHASE INVERSION (E)** • trace the signal amplitude and phase in phase inverter circuits employing conventional methods as well as complementary symmetry.	
Power gain, decibel Single-ended, transformerless Collector dissipation, Heat sink	**POWER AMPLIFIER (E)** • test the power gain of an audio output stage.	
Tuned input and output R.F. and I.F. amplifier Selectivity, bandwidth Critical coupling	**TUNED CIRCUITS (E)** • examine the response of a tuned circuit to various input signals. **TUNED AMPLIFIERS (E)** • examine the response of a tuned amplifier to various frequencies. • tune the stage to a given frequency.	The circuits listed for 232.4 to 232. semiconductor versions. R.F. amplifiers should not be omit studied.
Amplitude modulation, carrier Modulating frequency Sidebands, per cent modulation Sensitivity, signal-to-noise ratio Intermediate frequency Frequency modulation Sidebands, carrier, deviation, centre frequency Modulation index		

ggestions for Student Activity	Discussion
SION (E) gnal amplitude and phase in phase inverter circuits nventional methods as well as complementary **IFIER (E)** er gain of an audio output stage.	
ITS (E) response of a tuned circuit to various input signals. **FIERS (E)** e response of a tuned amplifier to various fre- ge to a given frequency.	The circuits listed for 232.4 to 232.7 may be taught in both vacuum tube and semiconductor versions. R.F. amplifiers should not be omitted if radio receivers (Section 24.3) are studied.

Section	Topic	Element	Cros Refere
23.2 Circuits using amplifying devices (continued)	**232.4 R.F. amplifiers**	2324.5 FM R.F. and I.F. circuits (O)	154.2 154.4
		2324.6 FM limiter (O)	
		2324.7 Mixer (O)	
	232.5 Oscillators	2325.1 Conditions for sustained oscillations	1326.2 1513.1
		2325.2 L-C types	24.3 1312.3 25.4
		2325.3 Crystal controlled (O)	154.2 154.4 1113.6
		2325.4 Types	
		2325.5 Negative resistance types	153.4 2451.4 253.1 1514.2
		2325.6 R-C sine wave	254.1
	232.6 Pulse Circuits (O)	2326.1 Non-sinusoidal waveforms	1514.3

UNIT: 2.3 Basic Electronic Circuits

Topic	Element	Cross-Reference	Fundamentals
R.F. amplifiers	2324.5 FM R.F. and I.F. circuits (O)	154.2 154.4	
	2324.6 FM limiter (O)		Limiting
	2324.7 Mixer (O)		Heterodyne
Oscillators	2325.1 Conditions for sustained oscillations	1326.2 1513.1	Feedback systems (C) Negative resistance Oscillation
	2325.2 L-C types	24.3 1312.3 25.4	Resonance (C) $f_0 = \frac{1}{2\pi\sqrt{LC}}$
	2325.3 Crystal controlled (O)	154.2 154.4 1113.6	
	2325.4 Types	153.4	Piezoelectric crystal characteristics
	2325.5 Negative resistance types	2451.4 253.1 1514.2	
	2325.6 R-C sine wave	254.1	Negative resistance
Pulse Circuits (O)	2326.1 Non-sinusoidal waveforms	1514.3	Fourier analysis

Technical Terms	Suggestions for Student Activity	D
First-order sidebands Overcoupling, wideband Amplitude limitation Nonlinearity, heterodyne Converter	**FM ALIGNMENT (E)** • use a sweep generator to align an FM I.F. amplifier.	
Oscillator, feedback regeneration, degeneration Tank circuit, damping Hartley, colpitts Resonance, Q Crystal, quartz, X cut, Y cut, AT cut Nonsinusoidal Multivibrator, relaxation and blocking oscillators Tunnel diode, transitron Wien bridge, phase shift	**L-C OSCILLATORS (E)** • set up, observe and make measurements on one or more types of L-C oscillators. **OTHER OSCILLATORS (E)** • set up, observe and make measurements on one or more types of crystal, R-C or negative resistance oscillators.	The fundamental conditions r amplitude should be grasped b At least one L-C and one R-C allow the student a good ins quency, waveshape, and stabi
		TV, C.R.O. and radar circuits many of these waveforms. The teacher should be aware need not be fully conversant w

uggestions for Student Activity	Discussion
MENT (E) eep generator to align an FM I.F. amplifier.	
ATORS (E) serve and make measurements on one or more types ators. **CILLATORS (E)** serve and make measurements on one or more types -C or negative resistance oscillators.	The fundamental conditions requiring feedback in the correct phase and amplitude should be grasped by the student. At least one L-C and one R-C type should be studied in enough depth to allow the student a good insight into the design features governing frequency, waveshape, and stability.
	TV, C.R.O. and radar circuits provide a ready source for demonstrating many of these waveforms. The teacher should be aware of what can be done with Fourier analysis but need not be fully conversant with the mechanics of its use.

Section	Topic	Element	Cross Referen
23.2 Circuits using amplifying devices (continued)	**232.6 Pulse circuits (continued)**	2326.2 Pulse forming and shaping	244.2 245.1
		2326.3 Triggered circuits	25.3
		2326.4 Simple electronic digital counter	
	232.7 Logic circuits (O)	2327.1 AND gate	24.4
		2327.2 OR gate	
		2327.3 Inverter circuits	
	232.8 S.C.R. circuits	2328.1 Simple static switch	1411.4 2223.6
		2328.2 Simple gate current control	242.3
		2328.3 Phase control of gate current	242.2
		2328.4 Trigger control of gate current	151.3

UNIT: 2.3 Basic Electronic Circuits

Topic	Element	Cross-Reference	Fundamentals
232.6 Pulse circuits (continued)	2326.2 Pulse forming and shaping	244.2 245.1	
	2326.3 Triggered circuits	25.3	Bistable circuits Triggered cycling
	2326.4 Simple electronic digital counter		
232.7 Logic circuits (O)	2327.1 AND gate	24.4	AB = A and B
	2327.2 OR gate		A + B = A or B
	2327.3 Inverter circuits		Cumulative Laws Associative Laws Distributive Laws DeMorgan's Theorem A = not A
232.8 S.C.R. circuits	2328.1 Simple static switch	1411.4 2223.6	Phase relationships
	2328.2 Simple gate current control	242.3	Switching (C)
	2328.3 Phase control of gate current	242.2	
	2328.4 Trigger control of gate current	151.3	

Technical Terms	Suggestions for Student Activity	Dis
Multivibrator, blocking oscillator, ringing circuit, differentiation, integration, clipping Triggered circuit, astable Monostable, bistable, flip-flop Synchronizing action	**PULSE FORMING AND SHAPING (E)** • set up and examine the operation of two or more pulse forming and shaping circuits. **TRIGGERED CIRCUITS (E)** • set up a multivibrator and examine its operation when triggered in the astable monostable and bistable modes.	Development of the use of Kirc tion circuit is valuable.
	LOGIC CIRCUITS (E) • set up and test some typical logic circuits and apply truth tables to their operation where applicable.	Logic circuits are identical in
Octave, decade Trigger voltage Retard angle Phase control Triggering current Firing voltage	**S.C.R. CIRCUITS (E)** • set up simple S.C.R. circuits utilizing the various methods of gate current control.	These circuits operate from an some load. The light dimmer c student project.

Suggestions for Student Activity	Discussion
RMING AND SHAPING (E) d examine the operation of two or more pulse forming circuits.	Development of the use of Kirchhoff's Laws in the differentiation/integration circuit is valuable.
CIRCUITS (E) multivibrator and examine its operation when triggered le monostable and bistable modes.	
CUITS (E) d test some typical logic circuits and apply truth tables ration where applicable.	Logic circuits are identical in function with common switching devices.
UITS (E) mple S.C.R. circuits utilizing the various methods of control.	These circuits operate from an A.C. source and control the current through some load. The light dimmer circuit makes an inexpensive "take home" student project.

UNIT: 2.3 Basic El

Section	Topic	Element	Cro Refer
23.3 Special Circuits (O)	**233.1 Microwave oscillators and amplifiers**	2331.1 Magnetrons	1121.
		2331.2 Klystrons, etc.	1112.
		2331.3 Travelling wave tubes	
		2331.4 Carcinotrons	
	233.2 Cryogenics		1115.
	233.3 Special effect devices	2333.1 Hall effect devices used in gauss meter applications	
		2333.2 Peltier effect used in cooling devices	1113.
	233.4 Relaxation circuits	2334.1 Gas diode relaxation circuits	
		2334.2 Relay as a relaxation device	21.1 253.1
	233.5 Infrared devices and circuits	2335.1 Elementary ideas of infrared radiation	
		2335.2 Elementary concepts of infrared detection	

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UNIT: 2.3 Basic Electronic Circuits

Topic	Element	Cross-Reference	Fundamentals
Microwave oscillators and amplifiers	2331.1 Magnetrons	1121.1	Electron Physics
	2331.2 Klystrons, etc.	1112.4	
	2331.3 Travelling wave tubes		
	2331.4 Carcinotrons		
Cryogenics		1115.1	Low temperature effects
Special effect devices	2333.1 Hall effect devices used in gauss meter applications		The Hall effect
	2333.2 Peltier effect used in cooling devices	1113.4	The Peltier effect
Relaxation circuits	2334.1 Gas diode relaxation circuits		Ionization of gases
	2334.2 Relay as a relaxation device	21.1 253.1	
Infrared devices and circuits	2335.1 Elementary ideas of infrared radiation		Infrared radiation
	2335.2 Elementary concepts of infrared detection		

Technical Terms	Suggestions for Student Activity	Dis
Waveguides Parabolic reflectors	**MICROWAVE TECHNOLOGY (A)** • research one or more of the areas indicated.	It is suggested that all topics i laneous Circuits) be listed as formed of current development a which are becoming more impor feel free to introduce unlisted development are becoming impor Very brief treatment of topics i student should be aware of the It is likely that some of the dev available as working models in sc
Superconductivity		
"Frigistor"		
Striking, sustaining and extinguishing voltages Self-interruption of coil current. Timing control (with coil shunt capacitor)	**RELAXATION CIRCUITS (E)** • design and build a sawtooth gas diode relaxation oscillator. • operate a relay as a vibrator or buzzer, and reduce the rate of operation by using capacitor and series resistance.	
Infrared detection	**INFRARED TECHNIQUES (A)** • do a research project with technical report.	

ggestions for Student Activity	Discussion
TECHNOLOGY (A) or more of the areas indicated.	It is suggested that all topics in this section (23.3 Special and Miscellaneous Circuits) be listed as OPTIONAL. The teacher should keep informed of current development and should increase the emphasis on topics which are becoming more important in the field. The teacher should also feel free to introduce unlisted topics which because of technological development are becoming important in electronics. Very brief treatment of topics in this section should be sufficient. The student should be aware of the elementary ideas and principles involved. It is likely that some of the devices mentioned here will not be readily available as working models in school laboratories.
CIRCUITS (E) uild a sawtooth gas diode relaxation oscillator. lay as a vibrator or buzzer, and reduce the rate of using capacitor and series resistance.	
CHNIQUES (A) n project with technical report.	

Section	Topic	Element	C Ref
23.3 Special Circuits (O) (continued)	**233.6 Timing circuits**	2336.1 Heat sensitive delays or timing devices	
		2336.2 Mechanical delays and timing circuits	242
		2336.3 Electronic delays and timing circuits	15
	233.7 Transmission line	2337.1 Types of transmission lines	
		2337.2 Theory of transmission lines	
	233.8 Tunnel diode circuits	2338.1 Tunnel diode oscillator	222

UNIT: 2.3 Basic Electronic Circuits

Topic	Element	Cross-Reference	Fundamentals
Timing circuits	2336.1 Heat sensitive delays or timing devices		Time constant
	2336.2 Mechanical delays and timing circuits	2424.2	
	2336.3 Electronic delays and timing circuits	153.4	
Transmission line	2337.1 Types of transmission lines		Wave theory Energy propagation
	2337.2 Theory of transmission lines		
Tunnel diode circuits	2338.1 Tunnel diode oscillator	2222.3	Negative resistance

Technical Terms	Suggestions for Student Activity	Dis
Bimetal operated delay switches Dashpot solenoid, clock-work delays and timers R-C and R-L delay circuits, electronic clock and counter circuits	**TIME DELAY STUDY (A)** • compare various timing circuits.	The time delay study could be don with construction and testing of s
Coaxial T line; open-wire T line Standing waves Current nodes and loops Voltage nodes and loops Characteristic Z_o		Transmission line theory can presentations using Grade 12 mat Students should be familiarized v by observing or using them. O voltage measurements and calcul

Suggestions for Student Activity	Discussion
ELAY STUDY (A) are various timing circuits.	The time delay study could be done as a student research project, complete with construction and testing of several types.
	Transmission line theory can involve higher mathematics; however, presentations using Grade 12 mathematics can be meaningful. Students should be familiarized with some of the common types of T lines by observing or using them. Open-wire lines are ideal for current and voltage measurements and calculation of Z_0.

DIVISION 2: Electronics

UNIT: 2.4 Ele

Section	Topic	Element	C Ref
24.1 Audio Amplifiers	**241.1 Sound Transducers**	2411.1 Human ear	111
		2411.2 Loudspeaker	132 241 24
		2411.3 Microphone	111 111 241
		2411.4 Phonograph cartridge	111 111
		2411.5 Tape heads; recording and playback	244 245
	241.2 Audio Amplification	2412.1 Block diagram of monaural amplifiers	23 23

UNIT: 2.4 Electronic Systems

Topic	Element	Cross-Reference	Fundamentals
41.1 Sound Transducers	2411.1 Human ear	111.6	Energy Transduction (C) $\text{db gain} = 10 \log \frac{P_{out}}{P_{in}}$ $= 20 \log \frac{E_{out}}{E_{in}}$
	2411.2 Loudspeaker	132.1 241.2 24.3	Motor principle
	2411.3 Microphone	1113.6 1113.3 241.2	Piezoelectric effect Generator principle
	2411.4 Phonograph cartridge	1113.6 1113.3	
	2411.5 Tape heads; recording and playback	2443.5 2452.2	Information storage
41.2 Audio Amplification	2412.1 Block diagram of monaural amplifiers	232.3 232.2	Amplification Feedback

Technical Terms	Suggestions for Student Activity	D
Transducer, logarithmic response Bel, decibel, volume unit phon		The logarithmic response of t frequency response should be c Transformation of energy from An elementary conception of t tion on magnetic iron oxide mat
Speaker impedance, power rating, frequency response, resonance Enclosure, baffle	**THE LOUDSPEAKER (E)** • examine physical construction. • observe the effects of baffles and enclosures. • make electrical measurements of audio power.	
Types: dynamic, crystal, ceramic, carbon Patterns: cardioid, omni-directional	**MICROPHONES (E)** • examine and use various types.	
Monaural, stereo, stylus pressure, tracking	**PHONOGRAPH CARTRIDGE (E)** • check for wear. • set pressure. • examine electrically.	
Tape speeds, multitrack Erase, bias Ferric oxide	**TAPE RECORDER (E)** • record and playback information from various sources. • examine electrically input, output, and bias signals.	
Preamplifier, output stage Phase inverter, splitter Feedback circuit Linear amplifier		An elementary conception of th tion on magnetic iron oxide mat

uggestions for Student Activity	Discussion
	The logarithmic response of the human ear to power variations and its frequency response should be discussed. Transformation of energy from one form to another is demonstrated here. An elementary conception of the process of magnetically storing information on magnetic iron oxide material should be given.
PEAKER (E) hysical construction. e effects of baffles and enclosures. trical measurements of audio power.	
IES (E) nd use various types.	
H CARTRIDGE (E) vear. re. ectrically.	
DER (E) playback information from various sources. ectrically input, output, and bias signals.	
	An elementary conception of the process of magnetically storing information on magnetic iron oxide material should be given.

Section	Topic	Element	R
24.1 Audio Amplifiers (continued)	241.2 Audio Amplification (continued)	2412.2 Detailed system configurations and interstage coupling methods	2 2 2 2
		2412.3 System specifications	
	241.3 High Fidelity	2413.1 Tone control circuits	
		2413.2 Complex loudspeaker systems	
		2413.3 Stereo systems	2
		2413.4 Feedback circuits	

UNIT: 2.4 Electronic Systems

Topic	Element	Cross-Reference	Fundamentals
Audio Amplification (continued)	2412.2 Detailed system configurations and interstage coupling methods	2321.5 2322.3 2323.4 2323.6	
	2412.3 System specifications		Intermodulation $db = 10 \log \frac{P_{out}}{P_{in}}$
High Fidelity	2413.1 Tone control circuits	153.5 153.6	Filters
	2413.2 Complex loudspeaker systems		
	2413.3 Stereo systems	232.5	Dimensional perception
	2413.4 Feedback circuits		

Technical Terms	Suggestions for Student Activity	Discu
Coupling: R-C, transformer, direct Configurations: push-pull, single-ended, phase inverter, phase splitter, complementary symmetry	**AMPLIFIER DESIGN (E)** • design and "breadboard" a simple two stage system incorporating voltage amplifier and output stage. • confirm design by measuring voltages, bias, gain, frequency response, etc. **AMPLIFIER TEST (E)** • test a high fidelity amplifier for harmonic and intermodulation distortion and power output.	
Frequency response, bandwidth intermodulation distortion Harmonic distortion, noise level, power rating		The relationship between power out is important. The student should be aware of the the industry.
Tone control, bass, treble roll-off, boost Tweeter, woofer, coaxial crossover, reverberations Balance	**HIGH FIDELITY EXPERIMENT (E) (O)** • observe subjectively the operation of a "hi-fi" amplifier compared with limited bandwidth amplifiers. • observe subjectively the operation of stereo amplifiers.	

Suggestions for Student Activity	Discussion
DESIGN (E) d "breadboard" a simple two stage system incorpora- amplifier and output stage. esign by measuring voltages, bias, gain, frequency c. **TEST (E)** h fidelity amplifier for harmonic and intermodulation d power output.	The relationship between power output and subjective loudness in decibels is important. The student should be aware of the wide variety of specifications used in the industry.
ITY EXPERIMENT (E) (O) ubjectively the operation of a "hi-fi" amplifier com- mited bandwidth amplifiers. ubjectively the operation of stereo amplifiers.	

Section	Topic	Element	Cross- Referenc
24.2 Industrial Control	**242.1 Photoelectric**	2421.1 Simple on-off controls	21.1
		2421.2 Lighting control	
		2421.3 Alarm systems	
		2421.4 Counting and sorting	2326.4
		2421.5 Filling, weighing, sorting	
		2421.6 Photovoltaic supplies	1113.5
		2421.7 Motion picture sound track	
	242.2 Motor control	2422.1 S.C.R. applications	1411.4
		2422.2 Thyratron and ignitron applications	151.3 232.8
		2422.3 Torque and speed controls	1.4
	242.3 Voltage and current regulation	2423.1 Series regulated power supply	242.3 231.3
		2423.2 Shunt regulated power supply	231.1
		2423.3 Applications in industrial D.C. supplies	
		2423.4 Regulation of light, temperature, speed, humidity	232.8

UNIT: 2.4 Electronic Systems

Topic	Element	Cross-Reference	Fundamentals
242.1 Photoelectric	2421.1 Simple on-off controls	21.1	Light sensitivity of chemicals Photovoltaic effect Conversion of energy
	2421.2 Lighting control		
	2421.3 Alarm systems		
	2421.4 Counting and sorting	2326.4	
	2421.5 Filling, weighing, sorting		
	2421.6 Photovoltaic supplies	1113.5	
	2421.7 Motion picture sound track		
242.2 Motor control	2422.1 S.C.R. applications	1411.4	Phase relationships Torque-speed-power relationships
	2422.2 Thyratron and ignitron applications	151.3 232.8	
	2422.3 Torque and speed controls	1.4	
242.3 Voltage and current regulation	2423.1 Series regulated power supply	242.3 231.3	Comparator bridge
	2423.2 Shunt regulated power supply	231.1	
	2423.3 Applications in industrial D.C. supplies		
	2423.4 Regulation of light, temperature, speed, humidity	232.8	

Technical Terms	Suggestions for Student Activity	Discu
Photoelectric Photoemissive, Photoconductive, photocathode, photovoltaic	**INDUSTRIAL PHOTOELECTRIC SYSTEM (E)** • mock-up and test a simple photoelectric control system. **PROJECTION PHOTOELECTRIC SYSTEM (E)** • examine and test the operation of a motion picture projector's photoelectric audio system.	
Counter EMF Constant-torque-variable-speed	**MOTOR CONTROL (E)** • demonstrate electronic motor control.	While thyratrons and ignitrons hav devices their similarity to S.C.R.'s consideration feasible. A commercial panel is desirable control. Industrial systems which regulate q are very common. Except for the se form of voltage or current regulati might be suggested to the studen amplifiers, and S.C.R.'s.
Pass components Reference voltage, current sensing Line regulation, load regulation Null amplifier	**SERIES REGULATED POWER SUPPLY (E)** • test the operation of a regulated power supply containing series, pass amplifiers, voltage reference devices and error amplifying circuits.	

Suggestions for Student Activity	Discussion
L PHOTOELECTRIC SYSTEM (E) and test a simple photoelectric control system. **N PHOTOELECTRIC SYSTEM (E)** and test the operation of a motion picture projector's ic audio system.	
NTROL (E) rate electronic motor control.	While thyratrons and ignitrons have not been considered under electron devices their similarity to S.C.R.'s in function should make a very brief consideration feasible. A commercial panel is desirable when demonstrating electronic motor control. Industrial systems which regulate quantities such as light and temperature are very common. Except for the sensors or transducers, most utilize some form of voltage or current regulation. The wide variety of methods in use might be suggested to the student by examining systems using linear amplifiers, and S.C.R.'s.
ULATED POWER SUPPLY (E) peration of a regulated power supply containing series, iers, voltage reference devices and error amplifying	

DIVISION 2: Electronics

UNIT: 2.4 Elec

Section	Topic	Element	Cros Refere
24.2 Industrial Control (continued)	**242.4 Welding**	2424.1 Electronics in resistance welding	111.6 1411.4 233.6
		2424.2 Electronics in arc welding	
	242.5 High frequency heating	2425.1 Dielectric heating applications	1531.5
		2425.2 Induction heating applications	1116.2 171.7
24.3 Radio Receivers	**243.1 TRF receiver**	2431.1 AM carrier	2324.2
		2431.2 Block diagram	
		2431.3 Detailed circuit study	
	243.2 Superheterodyne receiver	2432.1 Block diagram and basic theory	2324.2

UNIT: 2.4 Electronic Systems

Topic	Element	Cross-Reference	Fundamentals
2.4 Welding	2424.1 Electronics in resistance welding	111.6 1411.4 233.6	Phase relationships Fusion of metals
	2424.2 Electronics in arc welding		
2.5 High frequency heating	2425.1 Dielectric heating applications	1531.5	Dielectric losses
	2425.2 Induction heating applications	1116.2 171.7	Eddy current losses Hysteresis losses
3.1 TRF receiver	2431.1 AM carrier	2324.2	Resonance
	2431.2 Block diagram		Selectivity (C)
	2431.3 Detailed circuit study		
3.2 Superheterodyne receiver	2432.1 Block diagram and basic theory	2324.2	Intermodulation Heterodyne Systems approach

Technical Terms	Suggestions for Student Activity	Dis
	WELDING CONTROL (E) • operate and test an electronic welding timer circuit.	
	HIGH FREQUENCY HEATING (A) • research and report on one or more industrial applications of high frequency heating.	Emphasis should be placed on avoided. Field trips would be useful in o many kinds.
Selectivity, sensitivity, detection, sidebands	**CONSTRUCT AND TEST A "CRYSTAL SET" (E)** • set up a simple diode detector with tuned circuit, observe waveform and listen to performance.	
Heterodyne, mixer, superheterodyne, converter Intermediate frequency, image frequency Sidebands	**HETERODYNE EXPERIMENT (E)** • experiment to show that a non-linearity must be present to produce heterodyning.	Two signals in the 20-22 KHZ ra fed through a linear (high fidelit tone. Application of a diode ac difference frequency to be heard. the mixing of two signals in a n ference components.

uggestions for Student Activity	Discussion
ONTROL (E) d test an electronic welding timer circuit.	
JENCY HEATING (A) nd report on one or more industrial applications of cy heating.	Emphasis should be placed on the use of losses which are normally avoided. Field trips would be useful in order to demonstrate industrial controls of many kinds.
AND TEST A "CRYSTAL SET" (E) nple diode detector with tuned circuit, observe wave- en to performance.	
E EXPERIMENT (E) t to show that a non-linearity must be present to rodyning.	Two signals in the 20-22 KHZ range, mixed in a resistive network can be fed through a linear (high fidelity) amplifier without producing an audible tone. Application of a diode across the input will cause a tone at the difference frequency to be heard. The student will thus become aware that the mixing of two signals in a non-linear network produces sum and difference components.

Section	Topic	Element	Cros Refer
24.3 Radio Receivers (continued)	**243.2 Superheterodyne receiver (continued)**	2432.2 Detailed circuit study: R.F. section, oscillator, mixer, I.F., A.G.C. detector, audio	2314.1 232.1 232.3 232.4 232.5
		2432.3 Alignment (O)	254.2 254.3
	243.3 FM receiver	2433.1 FM carrier	2324.4
		2433.2 Block diagram of the FM receiver	2314. 2314. 232. 232. 232. 232. 232.

UNIT: 2.4 Electronic Systems

Topic	Element	Cross-Reference	Fundamentals
3.2 Superheterodyne receiver (continued)	2432.2 Detailed circuit study: R.F. section, oscillator, mixer, I.F., A.G.C. detector, audio	2314.1 232.1 232.3 232.4 232.5	Resonance Selectivity (C) Amplification Oscillation Modulation
	2432.3 Alignment (O)	254.2 254.3	
3.3 FM receiver	2433.1 FM carrier	2324.4	Resonance Selectivity (C) Amplification Oscillation Modulation
	2433.2 Block diagram of the FM receiver	2314.2 2314.3 232.1 232.2 232.3 232.4 232.5	Systems approach

Technical Terms	Suggestions for Student Activity	D
Tracking, image rejection selectivity, sensitivity Automatic gain control Bandwidth	**SUPERHETERODYNE STUDY (E)** Observe the operation of and make measurements on the following sections: • R.F. stage. • Converter stage. • I.F. stage. • Detector and A.G.C. • Audio stage.	This represents several expe understanding of the superhe The student should be made f
Trimmer, padder	**ALIGNMENT OF SUPERHETERODYNE (E) (O)** • align a superheterodyne using several standard techniques.	
Frequency modulation No-signal noise ratio	**FM RECEIVER (A)** Compare AM and FM receivers as to • Range of audio frequencies reproduced. • Ability to overcome electrical interference. • Range of received signal.	Discuss the advantages and li
Critical bandwidth Stagger tuning A.F.C. Limiters Detectors, discriminators	**FM RECEIVER (E)** • examine the component layout and signal waveform of an FM receiver.	The range of frequencies, as understood. The sweep-marke this time.

Suggestions for Student Activity	Discussion
ERODYNE STUDY (E) e operation of and make measurements on the follow- s: e. er stage. e. r and A.G.C. age.	This represents several experiments which are fundamental to thorough understanding of the superheterodyne. The student should be made familiar with both tube and transistor models.
IT OF SUPERHETERODYNE (E) (O) uperheterodyne using several standard techniques.	
VER (A) M and FM receivers as to f audio frequencies reproduced. o overcome electrical interference. f received signal.	Discuss the advantages and limitations of FM reception.
VER (E) the component layout and signal waveform of an FM	The range of frequencies, as well as the function, of each block should be understood. The sweep-marker generator could be effectively introduced at this time.

Section	Topic	Element
24.4 Digital Computers	**244.1 Binary notation**	2441.1 Electrical advantages of the binary system
		2441.2 Binary counting
		2441.3 Binary addition
	244.2 Digital sub-systems	2442.1 Binary electrical circuits
		2442.2 Binary counter
		2442.3 Half-adder
		2442.4 Ring counter
		2442.5 Automatic control systems
	244.3 Basic computer system (block diagram)	2443.1 Interblock information flowlines
		2443.2 Input/output devices
		2443.3 Arithmetic unit
		2443.4 Control unit
		2443.5 Memory storage unit

UNIT: 2.4 Electronic Systems

Topic	Element	Cross-Reference	Fundamentals
244.1 Binary notation	2441.1 Electrical advantages of the binary system	232.7	Number systems
	2441.2 Binary counting		Binary
	2441.3 Binary addition		
244.2 Digital sub-systems	2442.1 Binary electrical circuits	232.6 232.7	Bistable devices
	2442.2 Binary counter		
	2442.3 Half-adder		
	2442.4 Ring counter		
	2442.5 Automatic control systems		Automation
244.3 Basic computer system (block diagram)	2443.1 Interblock information flowlines		Computation Systems approach
	2443.2 Input/output devices		Interfacing
	2443.3 Arithmetic unit	232.6	
	2443.4 Control unit	232.7	
	2443.5 Memory storage unit	2411.5	Information storage Memory (C)

Technical Terms	Suggestions for Student Activity	D
Binary numbers, base Encoder, decoder Octal representation	**BINARY BASICS (E)** • perform various tests on and become familiar with electrically bistable units (relays, flip-flop, etc.) either constructed by the student or assembled from kits. • Two-state devices. • Basic counters. • Readouts. • Simple adders.	Computers and data processin of electronic technology. The study. However, the teacher s as familiar with the functions radio, amplifiers, and televisio In order to maintain motivatio the system under study perfor
Bistable multivibrator, flip-flop Set, reset Magnetic Core Half-adder, full adder Truth table Ring counter	**CONTROL SYSTEM MOCK-UP (E)** • mock-up a system for control involving counting device.	
Program, operation Input device, arithmetic unit, memory unit Control unit, accumulator output device Punched, marked cards and tapes, magnetic tapes Card readers, key punch Program, clock, pulser Read, reset, count Register, address, hold Magnetic cores, discs, drums	**COMPUTER OBSERVATION (E)** • visit and observe a medium-to-large computer installation. **INPUT/OUTPUT DEVICES (E)** • examine, prepare and read examples of tapes and cards. **INFORMATION STORAGE (E)** • examine examples of storage devices. • use a bank of storage devices to store data.	

stions for Student Activity

E)
tests on and become familiar with electrically
ays, flip-flop, etc.) either constructed by the
ed from kits.
s.

MOCK-UP (E)
n for control involving counting device.

RVATION (E)
e a medium-to-large computer installation.

EVICES (E)
e and read examples of tapes and cards.

ORAGE (E)
es of storage devices.
orage devices to store data.

Discussion

Computers and data processing are prominent as examples of the progress of electronic technology. They provide excellent material for a systems study. However, the teacher should be aware that the students will not be as familiar with the functions of this type of equipment as they are with radio, amplifiers, and television.

In order to maintain motivation, teachers will have to take steps to make the system under study perform interesting and understandable functions.

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Section	Topic	Element
24.5 Television	**245.1 TV receiver**	2451.1 Transmitted signal
		2451.2 TV channel
		2451.3 TV raster
		2451.4 TV receiver block diagram

UNIT: 2.4 Electronic Systems

Topic	Element	Cross-Reference	Fundamentals
.1 TV receiver	2451.1 Transmitted signal	2324.2 2324.4	Sequential scanning of object Resolution Z-axis modulation
	2451.2 TV channel		Selectivity (C)
	2451.3 TV raster	221.6 253.1	Luminescence Time-base Modulation
	2451.4 TV receiver block diagram	232.6 253.1	Systems approach

Technical Terms	Suggestions for Student Activity	Di
Video, audio information TV channels Resolution, vestigial sideband Sound carrier, video carrier Bandwidth	**TRANSMITTED TV SIGNAL (E)** • make use of a test pattern. • observe a composite video signal.	The TV receiver is an excellen variety of different circuits. Th introduced.
VHF and UHF channels I.F. response curve Video and audio carriers		
Raster Frame frequency Field frequency Horizontal frequency Interlaced scanning "Ghost" images	**TV RASTER (E)** • observe the scanning lines of a raster. • show the effect of horizontal and vertical oscillator adjustment.	
Tuner Video I.F. amplifier Video detector and amplifiers Sync separator and amplifier A.F.C. intercarrier Horizontal and vertical deflection circuits "Pix"	**TV RECEIVER BLOCK DIAGRAM (E)** • examine the signal waveforms at key test points of the TV receiver (P).	Safety should be stressed pa system, to the isolation syster chassis from ground, and the ha

gestions for Student Activity	Discussion
V SIGNAL (E) test pattern. posite video signal.	The TV receiver is an excellent example of a system involving a wide variety of different circuits. The "systems" approach can be profitably introduced.
canning lines of a raster. ct of horizontal and vertical oscillator adjustment.	
LOCK DIAGRAM (E) signal waveforms at key test points of the TV	Safety should be stressed particularly in relation to the high voltage system, to the isolation system, to the isolation of the transformerless chassis from ground, and the handling of cathode ray tubes.

Section	Topic	Element
24.5 Television (continued)	**245.1 TV receiver (continued)**	2451.5 TV receiver controls
	245.2 Closed-circuit and broadcast systems	2452.1 Closed-circuit system fundamentals 2452.2 Video tape recording 2452.3 TV broadcast fundamentals

UNIT: 2.4 Electronic Systems

Topic	Element	Cross-Reference	Fundamentals
45.1 **TV receiver (continued)**	2451.5 TV receiver controls	253.3	Synchronization (C) Linearity
45.2 **Closed-circuit and broadcast systems**	2452.1 Closed-circuit system fundamentals		Systems approach
	2452.2 Video tape recording	2411.5	Information storage
	2452.3 TV broadcast fundamentals	2324.2	Radiation

Technical Terms	Suggestions for Student Activity	
Fine tuning control Contrast control Brightness control Vertical hold control Height control Vertical linearity control Width control A.G.C. control	**TV RECEIVER CONTROLS (E)** • become familiar with the main controls of a TV receiver. • observe the effect on the TV receiver of basic faults.	The student should be able t and their function within the b Basic type of faults can be in tution of faulty tubes, or the switches.
Monitor, camera Coaxial cable Bandwidth, UHF, VHF Frequency allocation Network operation Rebroadcasting Geographical coverage Station interference	**USE OF CLOSED-CIRCUIT EQUIPMENT (E)** • connect and use a closed-circuit TV system. **VIDEO TAPE RECORDING (E)** • use a video tape recorder.	Since closed-circuit TV and v common, the student should principles. Some of the general princip

uggestions for Student Activity	Discussion
R CONTROLS (E) miliar with the main controls of a TV receiver. e effect on the TV receiver of basic faults.	The student should be able to recognize the purpose of the main controls and their function within the blocks of the TV receiver. Basic type of faults can be introduced by the removal of tubes, the substitution of faulty tubes, or the injection of circuit faults through a bank of switches.
OSED-CIRCUIT EQUIPMENT (E) nd use a closed-circuit TV system. **E RECORDING (E)** o tape recorder.	Since closed-circuit TV and video tape recording are becoming much more common, the student should have some familiarity with the broad general principles. Some of the general principles of TV broadcasting should be considered.

Section	Topic	Element
25.1 Conventional meters (as used in electronics)	**251.1 D.C. meters for electronics**	2511.1 Importance of low drain by voltmeters used in electronic circuits 2511.2 Ammeters, milliammeters, microammeters
	251.2 A.C. meters for electronics	2512.1 Rectifier circuits for A.C. half-wave and full-wave bridges. The effects of frequency, nonsinusoidal waveform, superposition of D.C. on A.C. effects of diode nonlinearity 2512.2 R.F. meters 2512.3 Special meters (VU, DB)
	251.3 VOM multimeter	2513.1 The need for the VOM in electronics 2513.2 Limitations, precautions to be observed, advantages and disadvantages with respect to the VTVM

UNIT: 2.5 Test Equipment

Topic	Element	Cross-Reference	Fundamentals
251.1 D.C. meters for electronics	2511.1 Importance of low drain by voltmeters used in electronic circuits 2511.2 Ammeters, milliammeters, microammeters	12.1 1321.1	Theory of measurements Motor principle Sensitivity (C)
251.2 A.C. meters for electronics	2512.1 Rectifier circuits for A.C. half-wave and full-wave bridges. The effects of frequency, nonsinusoidal waveform, superposition of D.C. on A.C. effects of diode nonlinearity 2512.2 R.F. meters 2512.3 Special meters (VU, DB)	12.2 1113.4	Fourier analysis of nonsinusoidal waveforms Rectification Superposition Thermocouples Logarithmic response $\text{db} = 10 \log \frac{P_{out}}{P_{in}}$
251.3 VOM multimeter	2513.1 The need for the VOM in electronics 2513.2 Limitations, precautions to be observed, advantages and disadvantages with respect to the VTVM	122.2	

Technical Terms	Suggestions for Student Activity	
Moving coil resistance Full-scale current Ohms per volt rating Circuit loading effect	**COIL RESISTANCE TEST (E) (O)** • determine the coil resistance of a microammeter.	The ohmmeter will dama half-scale" method. Rem
Volume unit, decibels	**FREQUENCY RESPONSE (E) (O)** • plot the frequency response of one or more A.C. meters.	Although no mathemati the knowledge that no sinusoidal waves should The students should be human body.
Input impedance	**VOM MULTIMETER (E)** • become proficient in the operation of a VOM multimeter.	

ggestions for Student Activity	Discussion
ANCE TEST (E) (O) he coil resistance of a microammeter.	The ohmmeter will damage a sensitive instrument. Use the "shunt-rheostat half-scale" method. Remove the rheostat and measure it with an ohmmeter.
RESPONSE (E) (O) quency response of one or more A.C. meters.	Although no mathematical treatment is suggested for waveform analysis, the knowledge that nonsinusoidal waves may be analyzed in terms of sinusoidal waves should be imparted. The students should be aware of the logarithmic response of parts of the human body.
METER (E) oficient in the operation of a VOM multimeter.	

Section	Topic	Element
25.2 The electronic voltmeter	**252.1 Theory of operation as a voltmeter**	2521.1 Basic principles: use of amplifier to protect movement and increase sensitivity
		2521.2 Slideback circuit and other single amplifier circuits (O)
		2521.3 Basic two-amplifier bridge; principle of operation
		2521.4 Input circuit for direct voltage; sensitivity rating; comparison with VOM
		2521.5 Adaptation for alternating voltage measurement
	252.2 Theory of operation as an ohmmeter	2522.1 Basic concept: measurement of voltage across unknown resistance
		2522.2 Practical circuit consideration of complete electronic ohmmeter

UNIT: 2.5 Test Equipment

Topic	Element	Cross-Reference	Fundamentals
Theory of operation as a voltmeter	2521.1 Basic principles: use of amplifier to protect movement and increase sensitivity	232.1 232.3	D.C. amplification
	2521.2 Slideback circuit and other single amplifier circuits (O)		
	2521.3 Basic two-amplifier bridge; principle of operation	123.1	Bridge theory
	2521.4 Input circuit for direct voltage; sensitivity rating; comparison with VOM	251.1	Voltmeter sensitivity
	2521.5 Adaptation for alternating voltage measurement	122.1 221.1 222.2 231.1	
Theory of operation as an ohmmeter	2522.1 Basic concept: measurement of voltage across unknown resistance	121.3	The current and voltage method of determining resistance
	2522.2 Practical circuit consideration of complete electronic ohmmeter		

Technical Terms	Suggestions for Student Activity	
Ohms per volt rating, input impedance for D.C. and A.C. Frequency limitation	**THE ELECTRONIC VOLTMETER (E)** - become proficient in the operation of an electronic voltmeter.	At present (1967) the t used to cover all voltme voltmeter is not comm both types. Skill in its use will be bu tions in which it will be u It should be noted tha VTVM, e.g., higher impe
Ohms adjust Zero adjust	**THE OHMMETER (E)** - become proficient in the use of ohmmeters.	

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gestions for Student Activity	Discussion
C VOLTMETER (E) ient in the operation of an electronic voltmeter.	At present (1967) the term vacuum tube voltmeter (VTVM) is commonly used to cover all voltmeters employing amplifiers and the term transistor voltmeter is not common. "Electronic voltmeter" is intended to cover both types. Skill in its use will be built up in the many experimental and practical situations in which it will be used during the course. It should be noted that the VOM may have some advantages over the VTVM, e.g., higher impedance at high voltage ranges.
R (E) ient in the use of ohmmeters.	

Section	Topic	Element
25.3 Cathode ray oscilloscope (C.R.O.)	**253.1 Theory of operation**	2531.1 Fundamental concept of writing on a fluorescent screen with a controlled beam of electrons 2531.2 Circuitry study: • Sweep and blanking circuits • Deflection methods • Synchronizing • Block diagram • Broad band requirements of the vertical amplifier 2531.3 Other displays and methods: • B scan • Z axis modulation
	253.2 Applications of C.R.O.	2532.1 Examination of waveform for distortion, presence of unwanted signal components 2532.2 Measurement of frequency using calibrated sweep Z axis pips, Lissajou figures, roulette patterns 2532.3 Voltage measurement of D.C. and A.C.

UNIT: 2.5 Test Equipment

Topic	Element	Cross-Reference	Fundamentals
1 Theory of operation	2531.1 Fundamental concept of writing on a fluorescent screen with a controlled beam of electrons	12.2 2451.3	Time-based graphs Luminescence Systems approach Waveform analysis Frequency response of systems Modulation Graphical representations of variables other than time
	2531.2 Circuitry study: • Sweep and blanking circuits • Deflection methods • Synchronizing • Block diagram • Broad band requirements of the vertical amplifier	232.5 232.6 233.4	
	2531.3 Other displays and methods: • B scan • Z axis modulation	2451.4	
2 Applications of C.R.O.	2532.1 Examination of waveform for distortion, presence of unwanted signal components	151.2 151.4 231.1	Waveform analysis (Fourier analysis)
	2532.2 Measurement of frequency using calibrated sweep Z axis pips, Lissajou figures, roulette patterns	232.2 232.3 232.4 232.5 232.6 232.7	
	2532.3 Voltage measurement of D.C. and A.C.	26.1 251.1 251.2	

Technical Terms	Suggestions for Student Activity	
Vertical and horizontal deflection, electrostatic and electromagnetic deflection time Time base, deflection sensitivity Brilliance, focus Linearity		The C.R.O. is the most v hardly be overemphasiz A large number of stu many more will involve The B scan and Z axis grounding for TV.
Beam blanking Sweep frequency Vertical & horizontal bandwidth risetime Synchronization Triggered sweep		
Clipping Hum modulation	**TESTING THE C.R.O. (E)** Test for: • frequency response • time base linearity • sweep frequency • distortion **FREQUENCY MEASUREMENT (E)** • measure frequency by the Lissajou method	The laboratory should h wideband, plug-in- type ments.

uggestions for Student Activity	Discussion
	The C.R.O. is the most versaltile electronic instrument. Its importance can hardly be overemphasized. A large number of student activities will be built around the C.R.O. and many more will involve it as a measurement or display instrument. The B scan and Z axis modulation (used in radar) provide an excellent grounding for TV.
E C.R.O. (E) response linearity quency **MEASUREMENT (E)** requency by the Lissajou method	The laboratory should have at least one professional quality D.C. coupled wideband, plug-in- type C.R.O. in addition to sufficient student-type instruments.

Section	Topic	Element
25.3 Cathode ray oscilloscope (C.R.O.) (continued)	**253.2 Applications of C.R.O. (continued)**	2532.4 Pulse length and shape determination using a time and voltage-calibrated sweep
	253.3 Adjustment and use	2533.1 Operating and calibrating controls, understanding of and familiarization with
		2533.2 Interpreting C.R.O. Displays and precautions in using: • problems in synchronization • polarity reversals • amplitude distortion • capacitive loading
25.4 Signal generators	**254.1 Audio frequency signal generators**	2541.1 Circuit analysis
		2541.2 Use of A.F. generator

UNIT: 2.5 Test Equipment

Topic	Element	Cross-Reference	Fundamentals
253.2 Applications of C.R.O. (continued)	2532.4 Pulse length and shape determination using a time and voltage-calibrated sweep		Pulse Concept
253.3 Adjustment and use	2533.1 Operating and calibrating controls, understanding of and familiarization with	245.1	Calibration Scientific standards Theory of measurements Sources of errors
	2533.2 Interpreting C.R.O. Displays and precautions in using: • problems in synchronization • polarity reversals • amplitude distortion • capacitive loading		
254.1 Audio frequency signal generators	2541.1 Circuit analysis	2325.6	Frequency standards Audibility Sinusoidal and nonsinusoidal waveforms
	2541.2 Use of A.F. generator	261.3	Feedback (C)

Technical Terms	Suggestions for Student Activity	Disc
Pulse length Risetime Decay		
	OPERATION OF CATHODE RAY OSCILLOSCOPE (E) • become competent in the operation of the C.R.O. in order to observe or measure amplitude, time, waveform, and modulation.	Note that **use** of the oscilloscope tion.
Frequency stability Harmonic distortion	**AUDIO SIGNAL GENERATOR (E)** • become familiar with the use and adjustment of an audio signal generator.	If high quality earphones are ava tunity to self-test their hearing res Knowledge of the Fletcher-Munse

Suggestions for Student Activity	Discussion
OF CATHODE RAY OSCILLOSCOPE (E) competent in the operation of the C.R.O. in order to measure amplitude, time, waveform, and modulation.	Note that **use** of the oscilloscope will precede understanding of its operation.
NAL GENERATOR (E) amiliar with the use and adjustment of an audio signal	If high quality earphones are available, students should have the opportunity to self-test their hearing response. Knowledge of the Fletcher-Munsen curves would also be of interest.

Section	Topic	Element
25.4 Signal generators (continued)	**254.2 R.F. signal generators**	2542.1 Circuit analysis 2542.2 Use of r.f. signal generator
	254.3 Other types (O)	2543.1 Sweep generators: basic principle, performance specifications 2543.2 Pulse generators 2543.3 Colour bar and dot generators
25.5 Utilization of test equipment	**255.1 Exercise of proper care**	2551.1 Prevention of electrical damage 2551.2 Prevention of mechanical damage
	255.2 Selection and use	2552.1 Selection of proper equipment for a test 2552.2 Correct use of the test equipment selected

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UNIT: 2.5 Test Equipment

Topic	Element	Cross-Reference	Fundamentals
.2 R.F. signal generators	2542.1 Circuit analysis 2542.2 Use of r.f. signal generator	2325.2 2325.3	Frequency standards Feedback Modulation
.3 Other types (O)	2543.1 Sweep generators: basic principle, performance specifications 2543.2 Pulse generators 2543.3 Colour bar and dot generators	2325.2 2324.5 2325.4 2325.2	Frequency modulation Pulse concept
.1 Exercise of proper care	2551.1 Prevention of electrical damage 2551.2 Prevention of mechanical damage		Preventive maintenance
.2 Selection and use	2552.1 Selection of proper equipment for a test 2552.2 Correct use of the test equipment selected		Accuracy

Technical Terms	Suggestions for Student Activity	
Frequency stability Carrier Spurious oscillations, harmonics	**OPERATION OF R.F. GENERATOR (E)** • become familiar with the use of an r.f. generator.	Some design requirements s radiation leakage, and resista The use of the generators as under this topic.
Sweep frequency, sweep width Marker generator Rise and decay time	**OPERATION OF SWEEP GENERATOR (E) (O)** • become familiar with the use of an r.f. sweep generator.	
Parallax Performance specifications	**SELECTION OF INSTRUMENTS (E)** • make an intelligent selection of the most suitable instruments for several given situations.	Students must possess enou under test to choose correct tions, particularly of the acc drill in the selection of ins students' ability.

estions for Student Activity	Discussion
R.F. GENERATOR (E) ar with the use of an r.f. generator.	Some design requirements should be considered, e.g., frequency stability, radiation leakage, and resistance to pull-in. The use of the generators as service instruments is the only consideration under this topic.
SWEEP GENERATOR (E) (O) ar with the use of an r.f. sweep generator.	
INSTRUMENTS (E) igent selection of the most suitable instruments situations.	Students must possess enough knowledge of the equipment and the circuit under test to choose correctly. Knowledge of the performance specifications, particularly of the accuracy to be expected, is vital. Some form of drill in the selection of instruments may be useful in order to sharpen students' ability.

DIVISION 2: Electronics

UNIT: 2.6 Servici

Section	Topic	Element
26.1 Identification, isolation and correction of defects	**261.1 Initial discovery of fault or symptom**	2611.1 Physical examination 2611.2 Operation of the unit 2611.3 Control adjustment
	261.2 Identification of intermittent symptoms	2612.1 Application of pressure and vibration 2612.2 Operation at nonstandard voltage or temperature
	261.3 Isolation of defective stage	2613.1 Symptom analysis 2613.2 Signal substitution 2613.3 Bracketing 2613.4 Voltage and waveform measurement
	261.4 Isolation of defective component	2614.1 Observation and physical examination 2614.2 Testing of components and electron devices 2614.3 Voltage and current waveform measurements 2614.4 Component substitution
	261.5 Correction of defects	2615.1 Replacement of defective item 2615.2 Repair or adjustment of defective item 2615.3 Correction of design faults

UNIT: 2.6 Servicing and Test Procedures

Topic	Element	Cross-Reference	Fundamentals
1 Initial discovery of fault or symptom	2611.1 Physical examination		
	2611.2 Operation of the unit		
	2611.3 Control adjustment		
2 Identification of intermittent symptoms	2612.1 Application of pressure and vibration		Electrical and mechanical stresses
	2612.2 Operation at nonstandard voltage or temperature		Thermal effects
3 Isolation of defective stage	2613.1 Symptom analysis	254.1	Logic
	2613.2 Signal substitution	254.2	System analysis
	2613.3 Bracketing		
	2613.4 Voltage and waveform measurement	25.1 253.2	Amplitude Distortion
4 Isolation of defective component	2614.1 Observation and physical examination		Isolation (C)
	2614.2 Testing of components and electron devices	25.1 25.2	
	2614.3 Voltage and current waveform measurements	25.3	
	2614.4 Component substitution		
5 Correction of defects	2615.1 Replacement of defective item	271.3 27.2	
	2615.2 Repair or adjustment of defective item	27.3	
	2615.3 Correction of design faults		

Technical Terms	Suggestions for Student Activity	Dis
	IDENTIFICATION OF SIMPLE FAULT (E) • identify and correct a fault in a familiar circuit.	The two experiments suggested where the teacher knows what i lated the faults himself. Students should also be asked to his ability, on "live projects" w This may involve laboratory or sc belonging to other students or to
Symptom Intermittent Failure modes		
Distortion: amplitude, frequency and phase	**TROUBLE SHOOTING PRACTICE (E)** • identify and isolate faults in a system.	

gestions for Student Activity	Discussion
OF SIMPLE FAULT (E) orrect a fault in a familiar circuit.	The two experiments suggested should be introductory situations only, where the teacher knows what is wrong perhaps having artificially simulated the faults himself. Students should also be asked to do practical fault-finding, consistent with his ability, on "live projects" which become available in the laboratory. This may involve laboratory or school equipment which has failed or items belonging to other students or to staff members.
TING PRACTICE (E) olate faults in a system.	

Section	Topic	Element
26.2 Routine maintenance	**262.1 Advantages of routine maintenance**	2621.1 Replacement of short-life items before failure 2621.2 Detection of component drift through routine measurement procedure 2621.3 Maintaining tolerance by routine set-up procedure
	262.2 Alignment and calibration	2622.1 Need for adjustments 2622.2 Use of primary and secondary standards

UNIT: 2.6 Servicing and Test Procedures

Topic	Element	Cross-Reference	Fundamentals
Advantages of routine maintenance	2621.1 Replacement of short-life items before failure 2621.2 Detection of component drift through routine measurement procedure 2621.3 Maintaining tolerance by routine set-up procedure		Preventive maintenance Reliability theory
Alignment and calibration	2622.1 Need for adjustments 2622.2 Use of primary and secondary standards		Electrical standards Calibration (C)

Technical Terms	Suggestions for Student Activity	
Drift Random catastrophic failure Tolerance	**ROUTINE MAINTENANCE (E)** • perform the routine maintenance procedure on a piece of electronic equipment.	The students should be a equipment as part of their of the allotment for unit 2.7
Alignment Calibration Primary standard Secondary standard	**ALIGNMENT & CALIBRATION (E)** • perform the alignment and calibration procedure on a piece of electronic equipment.	

Suggestions for Student Activity	Discussion
E MAINTENANCE (E) rm the routine maintenance procedure on a piece of elec- quipment.	The students should be assigned the routine maintenance of laboratory equipment as part of their practical work. The time for this should come out of the allotment for unit 2.7.
MENT & CALIBRATION (E) rm the alignment and calibration procedure on a piece of ic equipment.	

DIVISION 2: Electronics

UNIT: 2.7 Construction M

Section	Topic	Element
27.1 Developmental methods using "conventional techniques"	**271.1 "Breadboard" construction**	2711.1 Pressed board 2711.2 Acrylic and fibre boards 2711.3 Leakage problems 2711.4 Hardware and methods of fastening 2711.5 Placement of components 2711.6 Pre-punched commercial boards and kits
	271.2 Metal chassis layout, forming, drilling and punching	2712.1 Advantages and disadvantages of various materials: steel, aluminum, copper, galvanized iron, tin plate 2712.2 Layout procedure: metal forming and fabricating.
	271.3 Placement and mounting of conventional components	2713.1 Heat dissipation 2713.2 Insulation requirements 2713.3 Electrostatic and electromagnetic interaction 2713.4 Environment: dust, oil, fumes, humidity, and ambient temperature 2713.5 Vibration, shock 2713.6 Machine screws

UNIT: 2.7 Construction Methods and Techniques

Topic	Element	Cross-Reference	Fundamentals
1.1 "Breadboard" construction	2711.1 Pressed board 2711.2 Acrylic and fibre boards 2711.3 Leakage problems 2711.4 Hardware and methods of fastening 2711.5 Placement of components 2711.6 Pre-punched commercial boards and kits	111.5	"Breadboarding" concept
1.2 Metal chassis layout, forming, drilling and punching	2712.1 Advantages and disadvantages of various materials: steel, aluminum, copper, galvanized iron, tin plate 2712.2 Layout procedure: metal forming and fabricating.	111.5	Conductivity Magnetic properties Workability
.3 Placement and mounting of conventional components	2713.1 Heat dissipation 2713.2 Insulation requirements 2713.3 Electrostatic and electromagnetic interaction 2713.4 Environment: dust, oil, fumes, humidity, and ambient temperature 2713.5 Vibration, shock 2713.6 Machine screws	111.6 212.1 111.5 153.1 152.1	Energy loss Electrostatic and magnetic fields Environmental effects

Technical Terms	Suggestions for Student Activity	
Acrylic, fibre	**"BREADBOARD" CONSTRUCTION (P)** • construct, in breadboarding fashion, several circuits.	For this unit, an allocation activity. This is to include w projects (2.7) and servicing include time for experimen specifically indicated elsew of 25 hours is suggested. Students should be able to have some experience in w Students should be able to holes, and use the tools m The teacher should be awa other subjects (machine sh to use methods and proced Much of the material on other lessons, preparatio execution of practical work
Skin effect Electroplating Scriber Chassis punches Brake Shear, nibbler	**CHASSIS PREPARATION (P)** • lay out, form, drill and punch chassis for electronic circuits.	
Wattage Ambient temperature		

gestions for Student Activity	Discussion
CONSTRUCTION (P) readboarding fashion, several circuits.	For this unit, an allocation of 50 hours minimum is suggested for student activity. This is to include work in constructing and testing practical student projects (2.7) and servicing (2.6) in actual repair situations. This does not include time for experiments, applications studies or graphical problems specifically indicated elsewhere in this guide. An optional extra allotment of 25 hours is suggested. Students should be able to identify the metals commonly used. They should have some experience in working such metals. Students should be able to sharpen a drill, select sizes for clearance, tap holes, and use the tools mentioned with some degree of competence. The teacher should be aware of what the student may have been taught in other subjects (machine shop, drafting, and sheet metal), and should strive to use methods and procedures which are in accordance with good practice. Much of the material on these pages will be presented as incidental to other lessons, preparations for experiments, and during planning and execution of practical work.
RATION (P) drill and punch chassis for electronic circuits.	

UNIT: 2.7 Construction Me

Section	Topic	Element
27.1 Developmental methods using "conventional techniques" (continued)	**271.3 Placement and mounting of conventional components (continued)**	2713.7 Methods of riveting 2713.8 Sockets for various components 2713.9 Grounding hardware 2713.10 Turrets 2713.11 Self-supporting components 2713.12 Grommets and other feedthrough devices 2713.13 Knobs, dial escutcheons, nameplates 2713.14 Locking washers and nuts
	271.4 Wiring layout and interconnecting methods	2714.1 Wiring colour codes 2714.2 Solder 2714.3 Soldering equipment 2714.4 Soldering methods 2714.5 Wire sizes, and current capacities 2714.6 Wire stranding 2714.7 Wire dress 2714.8 Cables and lacing 2714.9 Insulation on wire 2714.10 Special problems 2714.11 Conductor terminations
27.2 Printed or etched wiring	**272.1 Copperclad board (phenolic and fiberglass)**	2721.1 Silk screen and metal screen process 2721.2 Photosensitive methods

UNIT: 2.7 Construction Methods and Techniques

Topic	Element	Cross-Reference	Fundamentals
3 Placement and mounting of conventional components (continued)	2713.7 Methods of riveting 2713.8 Sockets for various components 2713.9 Grounding hardware 2713.10 Turrets 2713.11 Self-supporting components 2713.12 Grommets and other feedthrough devices 2713.13 Knobs, dial escutcheons, nameplates 2713.14 Locking washers and nuts		Fastening devices
4 Wiring layout and interconnecting methods	2714.1 Wiring colour codes 2714.2 Solder 2714.3 Soldering equipment 2714.4 Soldering methods 2714.5 Wire sizes, and current capacities 2714.6 Wire stranding 2714.7 Wire dress 2714.8 Cables and lacing 2714.9 Insulation on wire 2714.10 Special problems 2714.11 Conductor terminations		Coding Conductivity Classification systems
1 Copperclad board (phenolic and fiberglass)	2721.1 Silk screen and metal screen process 2721.2 Photosensitive methods		Printing process Etching process Chemical reactions Photosensitivity

Technical Terms	Suggestions for Student Activity	
Socket Turrets Grommets Grounding lug Escutcheon		
Colour coding Solder gun, pencil iron, solder bath and pot Multicore, heat sink Cable factor Solid, stranded, extra flexible Stray capacity Lacing Mylar, PVC, nylon, teflon Twisted pair, ground loops	**CONSTRUCTION OF ELECTRONIC EQUIPMENT (P)** • install components and interconnect them in the construction of electronic apparatus.	Workmanship of a high ful analysis of the opera evaluation of his skills.
Resist Exposure time, negative transparency		

estions for Student Activity	Discussion
OF ELECTRONIC EQUIPMENT (P) ents and interconnect them in the construction ratus.	Workmanship of a high order should be demanded of the student. A careful analysis of the operation of completed projects will be valuable in the evaluation of his skills.

Section	Topic	Element
27.2 Printed or etched wiring (continued)	272.1 Copperclad board (phenolic and fiberglass) (continued)	2721.3 Preparation of circuit layout artwork
		2721.4 Special components for printed circuit work
		2721.5 Resists
		2721.6 Etching materials
	272.2 Plain board	2722.1 Conductive paints
		2722.2 Resistance paints
		2722.3 Adhesive-backed copper foil
27.3 Modular circuits	273.1 Turret types	2731.1 Conventional components mounted in prepackaged arrangements
	273.2 Packaged circuits	2732.1 Couplates — complete networks for specific applications molded into one component package
		2732.2 Complete circuit modules — transistorized throwaways
27.4 Miniaturization	274.1 Circuits using discrete but unconventional components	2741.1 Deposition of component elements on substrate
		2741.2 Miniaturized electron devices for micromodules
		2741.3 Miniaturized electrolytic capacitors
	274.2 Thin film techniques	2742.1 Multilayer deposition of elements

UNIT: 2.7 Construction Methods and Techniques

Topic	Element	Cross-Reference	Fundamentals
.1 Copperclad board (phenolic and fiberglass) (continued)	2721.3 Preparation of circuit layout artwork 2721.4 Special components for printed circuit work 2721.5 Resists 2721.6 Etching materials		
2 Plain board	2722.1 Conductive paints 2722.2 Resistance paints 2722.3 Adhesive-backed copper foil		
1 Turret types	2731.1 Conventional components mounted in prepackaged arrangements		Modular construction
2 Packaged circuits	2732.1 Couplates — complete networks for specific applications molded into one component package 2732.2 Complete circuit modules — transistorized throwaways		Integration
1 Circuits using discrete but unconventional components	2741.1 Deposition of component elements on substrate 2741.2 Miniaturized electron devices for micromodules 2741.3 Miniaturized electrolytic capacitors	1532.2	Miniaturization (C) Deposition Modular construction
.2 Thin film techniques	2742.1 Multilayer deposition of elements	111.5	Deposition

Technical Terms	Suggestions for Student Activity	
Etchant Resist Ferric chloride	**PRINTED CIRCUIT CONSTRUCTION (P)** • prepare a printed circuit board and wire it into a working circuit.	
Turret, tinkertoy, Cordwood, encapsulation		These are fully operat certain functions. Useful as demonstratio
Couplate Throwaway		
Substrate Alumina Ceramic Metal oxide Scribing Sandblast Component density	**MINIATURIZED CIRCUITS (E)** • study and make measurements on various commercial circuits which may be classified as modular or miniaturized.	Discuss methods of dep substrates, adjusting micro-modules. At this time it may be t advanced of the equipr however, should be cor reports by students.
Masking		This is possibly the mo should strive to keep in

ggestions for Student Activity	Discussion
UIT CONSTRUCTION (P) nted circuit board and wire it into a working circuit.	
	These are fully operational units which may be purchased to perform certain functions. Useful as demonstration units: siren, horn.
CIRCUITS (E) ake measurements on various commercial circuits lassified as modular or miniaturized.	Discuss methods of depositing resistive and capacitive element on ceramic substrates, adjusting values by micro-machining and assembling into micro-modules. At this time it may be too early to expect much practical work on the more advanced of the equipment types mentioned on this page. The methods, however, should be considered and might serve as the basis for research reports by students. This is possibly the most rapidly developing segment of the field. Teachers should strive to keep informed.

Section	Topic	Element
27.4 Miniaturization (continued)	274.3 Integrated circuits	2743.1 Semiconductor chips 2743.2 Masking and etching of chips 2743.3 Production of various electrical properties by diffusion techniques 2743.4 Production of "hybrid" circuits combining thin film, deposition, discrete elements and monolithic "moletronics".

UNIT: 2.7 Construction Methods and Techniques

Topic	Element	Cross-Reference	Fundamentals
.3 Integrated circuits	2743.1 Semiconductor chips	111.5	Integration
	2743.2 Masking and etching of chips	222.1	Diffusion
	2743.3 Production of various electrical properties by diffusion techniques		
	2743.4 Production of "hybrid" circuits combining thin film, deposition, discrete elements and monolithic "moletronics".		

Technical Terms	Suggestions for Student Activity	Dis
Diffusion Interconnects Integrated circuit Hybrid	**COMPARISON STUDY (A)** • compare the various methods of construction of electronic circuits as to many economic, mechanical, and electrical factors.	Integrated circuits are widely us As they become more common in will likely become more cogn apparatus as a system will becom

stions for Student Activity	Discussion
DY (A) rious methods of construction of electronic economic, mechanical, and electrical factors.	Integrated circuits are widely used in computers and space applications. As they become more common in household devices, the technician's skills will likely become more cognitive. Knowledge of the operation of apparatus as a system will become more relevant than manual techniques.

DIVISION 3: Installation and Maintenance

UNIT: 3.1 Tr

Section	Topic	Element
31.1 Apprenticeship	**311.1 Educational requirements**	3111.1 Minimal requirements by: labour organizations, Dept. of Labour 3111.2 Educational allowances
	311.2 Apprenticeship Act	3112.1 Length of apprenticeship 3112.2 Transfer between employers 3112.3 Training requirements 3112.4 Indenturing 3112.5 Rates of pay 3112.6 Responsibilities of employer and employee
31.2 Social structure of the trade	**312.1 Labour organization**	3121.1 Requirements of union 3121.2 Membership conditions 3121.3 Benefits
	312.2 Organizational structure	3122.1 Trade classifications
	312.3 Working conditions	3123.1 Seasonal aspects 3123.2 Remuneration 3123.3 Importance in society
31.3 External jurisdiction	**313.1 Licensing: municipal provincial**	3131.1 Trade examinations 3131.2 Examining centres
	313.2 Inspectors: municipal provincial	3132.1 Building inspectors 3132.2 Hydro inspectors

UNIT: 3.1 Trade Requirements

Topic	Element	Cross-Reference	Technical Terms
Educational requirements	3111.1 Minimal requirements by: labour organizations, Dept. of Labour 3111.2 Educational allowances	313.1	Union shop Closed shop
Apprenticeship Act	3112.1 Length of apprenticeship 3112.2 Transfer between employers 3112.3 Training requirements 3112.4 Indenturing 3112.5 Rates of pay 3112.6 Responsibilities of employer and employee	312.1 3111.1	Apprenticeship Indentured Designated Trade Contract
Labour organization	3121.1 Requirements of union 3121.2 Membership conditions 3121.3 Benefits		Stewards Superintendent President Business agent Dues Card Strike Lockout Picket Picket Line
Organizational structure	3122.1 Trade classifications	3111.1 312.1	Estimator Lineman Journeyman Master electrician Maintenance Construction
Working conditions	3123.1 Seasonal aspects 3123.2 Remuneration 3123.3 Importance in society	3111.1 312.1	
Licensing: municipal provincial	3131.1 Trade examinations 3131.2 Examining centres	3111.1	
Inspectors: municipal provincial	3132.1 Building inspectors 3132.2 Hydro inspectors	321.3	

Regulations	Suggestions for Student Activity	
Local union Municipal licensing	**TRADE REQUIREMENTS (P)** • research some facet of the electrical trade.	This unit should be integrate Maintenance, being introduce
Apprenticeship Act		
Union by-laws Labour by-laws		During the term of the cours meet representatives of labo Labour, to gain firsthand inf Students should be acquainte ment. A research assignment
Department of Labour		The importance of electricit interesting discussion; for e blackout could be discusse industry should be a matter standard of living in this co and its products.
Department of Labour Department of Education Central Mortgage and Housing Corporation Hydro Electric Power Commission		

uggestions for Student Activity	Discussion
UIREMENTS (P) ome facet of the electrical trade.	This unit should be integrated throughout the Division on Installation and Maintenance, being introduced at the appropriate times.
	During the term of the course, the students should have the opportunity to meet representatives of labour unions, employers and the Department of Labour, to gain firsthand information about apprenticeship of electricians.
	Students should be acquainted with the roles of labour, unions and management. A research assignment may be useful here.
	The importance of electricity in our society provides the subject for an interesting discussion; for example, the effects of a wide-spread electrical blackout could be discussed. The magnitude of the Canadian electrical industry should be a matter of research and discussion. The relatively high standard of living in this country is dependent on the electrical industry and its products.

DIVISION 3: Installation and Maintenance UNIT: 3.2 Ontario E

Section	Topic	Element
32.1 Provisions	**321.1 Object and scope**	3211.1 Minimum standards 3211.2 Exemption from code regulations
	321.2 Safety	3212.1 Recognition of hazards 3212.2 Protection of life and property
	321.3 Approval procedures	3213.1 Compliance with provincial authority 3213.2 Compliance with local authorities 3213.3 Inspection procedures
	321.4 Legality	3214.1 Canadian Standards Association 3214.2 Power Commission Act 3214.3 Electrical Inspection Department
	321.5 Implementation	3215.1 Sections 3215.2 Index 3215.3 Tables 3215.4 Appendices

UNIT: 3.2 Ontario Electrical Code (15th Ed.)

Topic	Element	Cross-Reference	Technical Terms
1 Object and scope	3211.1 Minimum standards 3211.2 Exemption from code regulations		C.S.A. C.E.C. Department of Transport
2 Safety	3212.1 Recognition of hazards 3212.2 Protection of life and property		Regulations Ontario Gazette
3 Approval procedures	3213.1 Compliance with provincial authority 3213.2 Compliance with local authorities 3213.3 Inspection procedures	31.3	Fees Permit Final approval Current permit Defect C.S.A. approval
4 Legality	3214.1 Canadian Standards Association 3214.2 Power Commission Act 3214.3 Electrical Inspection Department		Act of Parliament
5 Implementation	3215.1 Sections 3215.2 Index 3215.3 Tables 3215.4 Appendices		

Regulations	Suggestions for Student Activity	Di
	STUDY OF THE ONTARIO ELECTRICAL CODE (P) • become acquainted with the definitions, tables, architectural symbols, regulations and application of the code book.	The Canadian Electrical Code m further study being a continual application, scope, familiarizatio merit in assessing the student Ontario Hydro established provi
OEC — Section 2		
OEC — Section 0		
		The Canadian Standards Associ Companies Act in 1940 and, at tories. In 1950 it became an i Ontario Hydro, railway compani along with electrical manufactu

gestions for Student Activity	Discussion
ONTARIO ELECTRICAL CODE (P) ainted with the definitions, tables, architectural tions and application of the code book.	The Canadian Electrical Code may be presented in an introductory lesson, further study being a continual reference throughout the course as to its application, scope, familiarization and interpretation. Open-book tests have merit in assessing the students' comprehension of the rules and tables. Ontario Hydro established province-wide inspection in 1915.
	The Canadian Standards Association was established under the Dominion Companies Act in 1940 and, at that time, inaugurated its testing laboratories. In 1950 it became an independent association sponsored by the Ontario Hydro, railway companies, communications and electrical utilities along with electrical manufacturers.

Section	Topic	Element
33.1 Non-metallic sheathed cable (O)	331.1 Regulations	3311.1 Limitations 3311.2 Installation requirements 3311.3 Cable supports 3311.4 Cable protection 3311.5 Concealing of cable 3311.6 Grounding
	331.2 Installation procedures	3312.1 Practical wiring considerations
		3312.2 Conductor identification
		3312.3 Joining and terminating conductors
		3312.4 Circuit tests
		3312.5 Remote control wiring (O)
33.2 Armoured and aluminum sheathed cable	332.1 Regulations	3321.1 Limitations
		3321.2 Grounding continuity
	332.2 Installation procedures	3322.1 Cable preparation 3322.2 Installation techniques

Maintenance

UNIT: 3.3 Electrical Wiring Systems

Topic	Element	Cross-Reference	Technical Terms
egulations	3311.1 Limitations 3311.2 Installation requirements 3311.3 Cable supports 3311.4 Cable protection 3311.5 Concealing of cable		Loop systems N.M.S.C. Approved Grounded system
	3311.6 Grounding	3321.2	
nstallation rocedures	3312.1 Practical wiring considerations	111.4 3213.3	Lampholder, outlet, receptacle, box, connectors Structure terminology
	3312.2 Conductor identification	171.9 111.5	A.W.G. Live, neutral, ground and switched conductors
	3312.3 Joining and terminating conductors		Solderless connectors Crimping tools
	3312.4 Circuit tests	1114.1 121.3 121.4	Electrical continuity Continuity tests Ringers
	3312.5 Remote control wiring (O)	21.1 17.1	Plaster covers Relays Low voltage transformers, current limiting Momentary contact switches
egulations	3321.1 Limitations		Armour Antishort Aluminum sheath Bonding A.C., A.S., A.C.L.
	3321.2 Grounding continuity	3341.3	Bonding strip
nstallation ro:edures	3322.1 Cable preparation 3322.2 Installation techniques		Mechanical security Electrical security

	Suggestions for Student Activity	
OEC — Section 12		This section is optional o In all projects in Electri develop the students' a pictorial or connection colour coding system, co
OEC — Section 12	**NON-METALLIC SHEATHED CABLE (P)** • install a lampholder, duplex receptacle and an S.P. switch.	If the teacher feels that n be given involving two a two projects is advocate done on wiring boards.
OEC — Section 0		In all projects, emphasi conductors to terminals connections. The teacher may elect to practice in test procedur
OEC — Section 12	**SOLDERLESS CONNECTORS (A)** • compare types, uses and sizes of solderless connectors.	
OEC — Section 16	**REMOTE CONTROL (P)** • install remote control circuits as an extension of the N.M.S.C. project above, or completely wire the structure as a class project.	Remote control wiring ha analogies. A study of th makes an effective assign
OEC — Section 12	**ARMOURED CABLE (P)** • incorporate the installation of a three-ganged switch box; the switches should control various devices.	Emphasis should be pla termination and functio cutting armour and the co
OEC — Section 10		
OEC — Section 12		

gestions for Student Activity	Discussion
	This section is optional only if it has been covered in Grade 10. In all projects in Electrical Wiring Systems, the teacher should strive to develop the students' ability to convert line or schematic diagrams to pictorial or connection diagrams; also, he should stress the approved colour coding system, conductor terminology and circuit analysis.
SHEATHED CABLE (P) holder, duplex receptacle and an S.P. switch.	If the teacher feels that more projects are required, additional projects may be given involving two and three wire N.M.S.C.; however, a maximum of two projects is advocated in the structure. Additional projects should be done on wiring boards. In all projects, emphasis must be placed on the correct connections of conductors to terminals because of the potential hazard due to improper connections. The teacher may elect to place faults in wiring circuits to give the students practice in test procedures.
ONNECTORS (A) s, uses and sizes of solderless connectors.	
ROL (P) control circuits as an extension of the N.M.S.C. or completely wire the structure as a class	Remote control wiring has merit from its applications, circuit analysis and analogies. A study of the advantages and disadvantages of the system makes an effective assignment.
BLE (P) he installation of a three-ganged switch box; the control various devices.	Emphasis should be placed upon the following: the positioning, correct termination and functions of the bonding strip; approved methods of cutting armour and the correct types and uses of A.C. fittings.

Section	Topic	Element
33.2 Armoured and aluminum sheathed cable (continued)	**332.3 Testing armoured cable circuits**	3323.1 Continuity tests 3323.2 Test for grounds
	332.4 Aluminum sheathed cable	3324.1 Regulations 3324.2 Installation techniques
33.3 Electrical metallic tubing (E.M.T.)	**333.1 Regulations**	3331.1 Allowable sizes 3331.2 Limitations of use
	333.2 E.M.T. fittings	3332.1 Couplings and connectors
	333.3 E.M.T. installation	3333.1 Cutting, bending and shaping 3333.2 Fastening and anchoring devices
33.4 Rigid conduit	**334.1 Regulations**	3341.1 Types, sizes and bends 3341.2 Determination of conduit sizes 3341.3 Ground continuity 3341.4 Conduit supporting
	334.2 Rigid conduit preparation	3342.1 Tool requirements 3342.2 Thread cutting and reaming 3342.3 Bending and forming
	334.3 Rigid conduit installation	3343.1 Fastening and anchoring devices 3343.2 Draw-in of heavy cable 3343.3 Vertical runs
33.5 Special raceway systems	**335.1 Types**	3351.1 Surface 3351.2 Underfloor

UNIT: 3.3 Electrical Wiring Systems

Topic	Element	Cross-Reference	Technical Terms
Testing armoured cable circuits	3323.1 Continuity tests 3323.2 Test for grounds	3611.1	Accidental grounds Energized circuits De-energized circuits Grounds
Aluminum sheathed cable	3324.1 Regulations 3324.2 Installation techniques		
Regulations	3331.1 Allowable sizes 3331.2 Limitations of use		E.M.T. Corrosive-resistant material Galvanic action Draw-in: fishing, fish tape
E.M.T. fittings	3332.1 Couplings and connectors		Threadless connectors Couplings Insulated bushings Locknuts
E.M.T. installation	3333.1 Cutting, bending and shaping 3333.2 Fastening and anchoring devices	334.2 334.3	Offsets Saddles Follow bends Combination benders Hickeys
Regulations	3341.1 Types, sizes and bends 3341.2 Determination of conduit sizes 3341.3 Ground continuity 3341.4 Conduit supporting	3412.3	Draw-in
Rigid conduit preparation	3342.1 Tool requirements 3342.2 Thread cutting and reaming 3342.3 Bending and forming	333.3	Threading Stocks and dies Reaming
Rigid conduit installation	3343.1 Fastening and anchoring devices 3343.2 Draw-in of heavy cable 3343.3 Vertical runs	333.3	Bushings Condulet
Types	3351.1 Surface 3351.2 Underfloor		Cellular metal floor raceway Cable troughs Busways Gutters

Regulations	Suggestions for Student Activity	
	SWITCHES (A) • compare switches, examining types and ratings.	The teacher should develo grounds, continuity and bo ohmmeters, meggers and b
OEC — Section 12, Table 19	**ALUMINUM SHEATHED CABLE (P) (O)** • install circuits using aluminum sheathed cable.	It is important to be aware the use of aluminum sheath
OEC — Section 4, 12 OEC — Section 12	**ELECTRICAL METALLIC TUBING (P)** • install a circuit involving multi-control switches and E.M.T., e.g. one light controlled from two locations with a convenience outlet. The second phase of the project should provide three point control; that is, a four way switch replacing the convenience outlet.	The projects should be arra students to make an offset There may be many vari independent challenge for e A student requirement for material to provide familiari ments and broadening of kn Original and interesting tech should accompany the proje
OEC — Section 4, 12	**RIGID CONDUIT (P)** • install a circuit utilizing rigid conduit.	Each student should have th The teacher may incorporat project above, or incorporat distribution services in the i Conduit and conductor relat
OEC — Section 12	**SURFACE RACEWAY (P) (O)** • install a circuit involving "wiremold" type raceway and fittings.	This section may be treated different localities. Students could be given a re uses of the various raceways

tions for Student Activity	Discussion
, examining types and ratings.	The teacher should develop a practical and realistic system of tests for grounds, continuity and bonding. These tests should involve the use of ohmmeters, meggers and bell ringers.
HED CABLE (P) (O) ng aluminum sheathed cable.	It is important to be aware of the environmental conditions which require the use of aluminum sheathed cable instead of armoured cable.
LLIC TUBING (P) nvolving multi-control switches and E.M.T., lled from two locations with a convenience phase of the project should provide three is, a four way switch replacing the con-	The projects should be arranged so as to provide the opportunity for the students to make an offset and 90° bend in 1/2 E.M.T. and rigid conduit. There may be many variations of the basic circuit, to provide an independent challenge for each individual or group within the class. A student requirement for each job should include preparing a bill of material to provide familiarization with suppliers' catalogues, time requirements and broadening of knowledge of wiring materials in general. Original and interesting techniques of fishing conductors through raceways should accompany the project on E.M.T. and rigid conduit.
) lizing rigid conduit.	Each student should have the opportunity to do a project in rigid conduit. The teacher may incorporate this project as an extension of the E.M.T. project above, or incorporate it with the motor control unit, or as part of distribution services in the installation of the stack. Conduit and conductor relationships are dealt with under services.
Y (P) (O) olving "wiremold" type raceway and fittings.	This section may be treated as optional since its importance will vary in different localities. Students could be given a research project concerning types, purposes and uses of the various raceways and ducts.

DIVISION 3: Installation and Maintenance

UNIT: 3.4

Section	Topic	Element
34.1 Single-occupancy services	**341.1 Regulations**	3411.1 Service location 3411.2 Metering 3411.3 Control and protective equipment
	341.2 The single-phase three-wire system	3412.1 Transformer winding and voltages 3412.2 Kirchhoff's Current Law 3412.3 Grounded neutral 3412.4 Transmission potentials
	341.3 Service calculations	3413.1 Circuit loading 3413.2 Demand factor
	341.4 Service materials	3414.1 Current and voltage ratings of disconnects and panels 3414.2 Factors governing sizes and types of conductors 3414.3 Conduit and conductor relationships 3414.4 Fuse types and capacities 3414.5 Circuit breakers

UNIT: 3.4 Distribution Systems

pic	Element	Cross-Reference	Technical Terms
ulations	3411.1 Service location	342.1 343.2	Supply authority Inspection authority
	3411.2 Metering	122.4	Line and load Meter loops Sealable meter fitting
	3411.3 Control and protective equipment	111.5	Overcurrent devices
single-phase ee-wire system	3412.1 Transformer winding and voltages	171.9	Dual voltages Neutral Balanced and unbalanced loads
	3412.2 Kirchhoff's Current Law	111.4	
	3412.3 Grounded neutral	341.5	
	3412.4 Transmission potentials		
vice culations	3413.1 Circuit loading	111.4	Branch circuits Service conductors; feeders Demand factor Demand load
	3413.2 Demand factor	1116.3	
vice materials	3414.1 Current and voltage ratings of disconnects and panels		C.S.A. approval Dead front Types R, RW, RHW, T, TW, TWH rating of wires or cables Three-pole, solid neutral Ferrule and knife blade fuses Tamper-resistant fuses Time delay fuses Circuit breaker Plug fuse
	3414.2 Factors governing sizes and types of conductors	111.5	
	3414.3 Conduit and conductor relationships	3341.1	
	3414.4 Fuse types and capacities	112.4	
	3414.5 Circuit breakers		

Regulations	Suggestions for Student Activity	
OEC — Section 6		Students should underst authority, either rural or mu The contractor must be ad the supply authority and t between the customer and
	THREE-WIRE DISTRIBUTION SYSTEM (E) Study the circuit conditions under balanced and unbalanced loads with • open neutral. • closed neutral.	The importance of balanc stressed. In the experiment on balar amount of imbalancing; als three-phase four-wire serv
OEC — Section 8		Each student may be give in his own home. The student should learn demand factor for varying t
CSA OEC — Section 2 OEC — Section 70, Table 2 and 4 Section 4 and 6 OEC — Section 70, Table 5 OEC — Section 14	**FUSES (A)** • investigate the design of various types of fuses.	Where possible each pair service. This will illustrate and locations, fuse and bre rural and urban services.

uggestions for Student Activity	Discussion
	Students should understand the relationship between local supply authority, either rural or municipal, and Ontario Hydro. The contractor must be advised concerning the location of a service from the supply authority and the inspector. In so doing, he acts as a liaison between the customer and the supply authority.
DISTRIBUTION SYSTEM (E) cuit conditions under balanced and unbalanced loads al. tral.	The importance of balancing loads in service installations should be stressed. In the experiment on balancing load, precautions should be taken on the amount of imbalancing; also, the experiment should not be carried out on a three-phase four-wire service.
	Each student may be given an assignment to calculate the size of service in his own home. The student should learn the underlying reasons for the percentage of demand factor for varying types of loads.
the design of various types of fuses.	Where possible each pair of students should install a different type of service. This will illustrate to the class the types and variations of meters and locations, fuse and breaker panels, service masts, combination panels, rural and urban services.

Section	Topic	Element
34.1 Single-occupancy services (continued)	**341.5 Grounding**	3415.1 Regulations 3415.2 Methods of grounding 3415.3 Determination of ground conductor size 3415.4 Conductors to be grounded 3415.5 Bonding of service equipment
	341.6 Service installation	3416.1 Meter types; spacing 3416.2 Conduit preparation and fittings 3416.3 Mounting and anchoring disconnect and distribution panel 3416.4 Installing conductors 3416.5 Supply authority feeders 3416.6 Load connections
34.2 Multi-occupancy services	**342.1 Regulations**	3421.1 Demand factor 3421.2 Service locations
	342.2 Service layouts	3422.1 Types and methods of metering 3422.2 Disconnect switches 3422.3 Panel requirements 3422.4 Feeders and risers 3422.5 Interpretation of specifications and electrical drawings

Maintenance

UNIT: 3.4 Distribution Systems

Topic	Element	Cross-Reference	Technical Terms
Grounding	3415.1 Regulations 3415.2 Methods of grounding 3415.3 Determination of ground conductor size 3415.4 Conductors to be grounded 3415.5 Bonding of service equipment	3321.2 3341.3 3432.4 171.9	Artificial ground electrode Urban systems, rural system Ground electrodes Distribution systems
Service installation	3416.1 Meter types; spacing 3416.2 Conduit preparation and fittings 3416.3 Mounting and anchoring disconnect and distribution panel 3416.4 Installing conductors 3416.5 Supply authority feeders 3416.6 Load connections	122.4 33.4 171.9 111.4 171.4	Ground bushing Circuit breakers Stack Weatherhead Drip loops Current permit Service supply Neutral bar
Regulations	3421.1 Demand factor 3421.2 Service locations	341.1 341.3 111.6	
Service layouts	3422.1 Types and methods of metering 3422.2 Disconnect switches 3422.3 Panel requirements 3422.4 Feeders and risers 3422.5 Interpretation of specifications and electrical drawings	122.4 3414.1	Current transformers Potential transformers Risers Sub-panels Splitter boxes Troughs Terminal blocks Demand blocks Bus bars Transformer vaults

Regulations	Suggestions for Student Activity	
OEC — Section 6 OEC — Section 10, Table 18		The reasons for grounc be expanded and explai should be thoroughly di The instructor may intr to the service. Student ground service entranc
OEC — Section 10	**SINGLE OCCUPANCY SERVICE (P)** • construct a 100-ampere, 120-240 volt service.	
OEC — Section 6 OEC — Section 4, Table 1 and 3		
OEC — Section 6 and 8		
		Panel equipment shou provided.

gestions for Student Activity	Discussion
PANCY SERVICE (P) 00-ampere, 120-240 volt service.	The reasons for grounding, as outlined in Section 10-002 of OEC should be expanded and explained to the students at this time. The "how and why" should be thoroughly discussed, with emphasis on the safety aspects. The instructor may introduce mineral insulated cable as a means of supply to the service. Students should be aware of types of overhead and underground service entrances.
	Panel equipment should include the owner's panel and the services provided.

Section	Topic	Element
34.2 Multi-occupancy services (continued)	**342.3 Service entrance materials**	3423.1 Selection of the disconnect switch 3423.2 Determination of the size and type of conductors 3423.3 Determination of the size of conduit 3423.4 Sizes, types and uses of splitter boxes
	342.4 Installation	3424.1 Circuit 3424.2 Location of components
34.3 Three-phase services	**343.1 Types**	3431.1 Three-phase power service 3431.2 Three-phase, four-wire distribution service 3431.3 Applications of two basic types
	343.2 Regulations	3432.1 Service locations 3432.2 Metering methods 3432.3 Colour coding of conductors 3432.4 Grounding and bonding
	343.3 Metering	3433.1 Wiring diagram 3433.2 Meter cabinets 3433.3 Demand meters 3433.4 Polyphase K.W.H. meters
	343.4 Service calculations and materials	3434.1 Conductor and conduit sizes 3434.2 Physical size and ratings of disconnect switches and fuses 3434.3 Distribution of panels
	343.5 Installation	3435.1 Three-phase power service 3435.2 Three-phase, four-wire service

Maintenance

UNIT: 3.4 Distribution Systems

Topic	Element	Cross-Reference	Technical Terms
Service entrance materials	3423.1 Selection of the disconnect switch		MCM rating
	3423.2 Determination of the size and type of conductors	111.4	
	3423.3 Determination of the size of conduit	33.4	
	3423.4 Sizes, types and uses of splitter boxes		
Installation	3424.1 Circuit		
	3424.2 Location of components		
Types	3431.1 Three-phase power service	171.12	Phase
	3431.2 Three-phase, four-wire distribution service	16.1	Three-phase
	3431.3 Applications of two basic types		
Regulations	3432.1 Service locations	3411.1	
	3432.2 Metering methods	3421.2	
	3432.3 Colour coding of conductors	341.5	
	3432.4 Grounding and bonding	3453.2	
Metering	3433.1 Wiring diagram		Ticklers
	3433.2 Meter cabinets		Meter cabinet, splitter
	3433.3 Demand meters	122.4	
	3433.4 Polyphase K.W.H. meters	151.4	
Service calculations and materials	3434.1 Conductor and conduit sizes	341.3	Three-pole, single throw
	3434.2 Physical size and ratings of disconnect switches and fuses	342.3 3452.1	Interlock Spring-loaded
	3434.3 Distribution of panels	3452.2	
Installation	3435.1 Three-phase power service	161.3	
	3435.2 Three-phase, four-wire service	341.6 342.4	

Regulations	Suggestions for Student Activity	D
OEC — Section 6 and 8	**MULTIPLE OCCUPANCY SERVICE (P)** • construct a multiple occupancy service with feeders, risers and panels.	Due to the size and cost of eq lation may be a class project.
OEC — Section 6 Section 36 OEC — Section 6 OEC — Section 4 OEC — Section 10		Careful consideration should b segment of the course. Discon of performing several functior This equipment may be assem could be available for future dents should be made awar systems. Comments and desig
OEC — Section 6 Local authority	**THREE-PHASE SERVICES (P)** • design and construct a simple three-phase service for a motor load. Further development of the project could be the expansion of the circuit into a combination of power and lighting circuits (three-phase, four wire).	

estions for Student Activity	Discussion
PANCY SERVICE (P) ultiple occupancy service with feeders, risers	Due to the size and cost of equipment, the multi-occupancy service installation may be a class project.
ERVICES (P) nstruct a simple three-phase service for a motor elopment of the project could be the expansion o a combination of power and lighting circuits ur wire).	Careful consideration should be given to the purchase of equipment for this segment of the course. Disconnects and distribution panels may be capable of performing several functions, thus keeping costs to a minimum. This equipment may be assembled forming a permanent installation which could be available for future projects covering A.C. motor controls. Students should be made aware of the variations of power and lighting systems. Comments and design considerations should be discussed.

Section	Topic	Element
34.4 Transformer installation	**344.1 Categories**	3441.1 Single-phase
		3441.2 Three-phase
		3441.3 Auto-transformers
	344.2 Parts, nomenclature and identification	3442.1 Cores
		3442.2 Primary and secondary
		3442.3 Bushings
		3442.4 Taps and changing mechanisms
		3442.5 Cooling equipment
	344.3 Nameplate information	3443.1 Primary and secondary voltage
		3443.2 K.V.A. output rating
		3443.3 Polarity connections
		3443.4 Primary taps
		3443.5 Ratio changes
		3443.6 Impedance of transformers
	344.4 Transformer bank connections	3444.1 Polarity
		3444.2 Phasing
		3444.3 Star connections
		3444.4 Delta connections

UNIT: 3.4 Distribution Systems

Topic	Element	Cross-Reference	Technical Terms
4.1 Categories	3441.1 Single-phase	17.1	Air cooled
	3441.2 Three-phase	171.10	Liquid cooled
	3441.3 Auto-transformers		"Breathing"
4.2 Parts, nomenclature and identification	3442.1 Cores		Tubular coolers Oil-immersed Heat dissipation Convection cooling Thermosiphon circulation
	3442.2 Primary and secondary	17.1	
	3442.3 Bushings	1719.3	
	3442.4 Taps and changing mechanisms		
	3442.5 Cooling equipment	1717.7	
4.3 Nameplate information	3443.1 Primary and secondary voltage	1718.4	Additive Subtractive Impedance-volts
	3443.2 K.V.A. output rating	1719.1	
	3443.3 Polarity connections	1719.3	
	3443.4 Primary taps	171.3	
	3443.5 Ratio changes		
	3443.6 Impedance of transformers	152.8	
4.4 Transformer bank connections	3444.1 Polarity	17.1	Polarity
	3444.2 Phasing	161.2	Phasing
	3444.3 Star connections		Star
	3444.4 Delta connections	171.12	Delta

Regulations	Suggestions for Student Activity	Dis
OEC — Section 26		To show the various classificati purpose and service, the transfor authority must be approached in
	TRANSFORMERS (A) • compare the design of several kinds of power transformers.	
	TRANSFORMER BANK INSTALLATION (P) • make a simplified working model of a typical transformer bank installation based upon good practice as observed in several local installations.	The importance of disconnecting the primary with banked transf time, the significance of the sign

gestions for Student Activity	Discussion
S (A) esign of several kinds of power transformers.	To show the various classifications of transformers according to cooling, purpose and service, the transformer vault in the school may be used. Local authority must be approached in order to gain entry to the vault.
BANK INSTALLATION (P) fied working model of a typical transformer bank ed upon good practice as observed in several ns.	The importance of disconnecting the secondary load before disconnecting the primary with banked transformers should be stressed; at the same time, the significance of the sign, "Danger Backfeed," must be understood.

Section	Topic	Element
34.5 Transformer protection	**345.1 Primary and secondary fusing**	3451.1 Reclosing devices 3451.2 Dropout devices 3451.3 Remote control devices
	345.2 High-voltage protection	3452.1 Oil switches 3452.2 Disconnects
	345.3 Lightning protection	3453.1 Arrestors 3453.2 Grounding conductors

UNIT: 3.4 Distribution Systems

Topic	Element	Cross-Reference	Technical Terms
rimary and econdary fusing	3451.1 Reclosing devices 3451.2 Dropout devices 3451.3 Remote control devices	171.4 3414.4 3414.5	Network protection Short time delay Copper fuse links Interlocks
igh-voltage rotection	3452.1 Oil switches 3452.2 Disconnects	3434.2	Protection tube Arcing horn Copperweld High tensile strength alloy
ightning rotection	3453.1 Arrestors	111.2 3311.6 3321.2 341.5	Point discharge
	3453.2 Grounding conductors		

Regulations	Suggestions for Student Activity	
OEC — Section 36		
OEC — Section 36	**OVER-CURRENT AND UNDER-VOLTAGE PROTECTION (A) (O)** • study the construction and operation of drop-out fuse cutouts, oil fuse cutouts, reclosing fuses, reclosing circuit breakers, release devices for under-voltage protection.	The primary fuses will " between primary and se Reclosing devices will o and will reclose after a or three reclosings to av An accidental reverse p is blocked by arrangeme

stions for Student Activity	Discussion
ND UNDER-VOLTAGE PROTECTION (A) (O) uction and operation of drop-out fuse cutouts, reclosing fuses, reclosing circuit breakers, r under-voltage protection.	The primary fuses will "blow" if a breakdown of the transformer insulation between primary and secondary winding occurs. Reclosing devices will open instantly to protect overhead primary networks and will reclose after a preset time delay. They will remain open after two or three reclosings to avoid supplying power into permanent short circuits. An accidental reverse power backfeed from the transformers to the main is blocked by arrangements of circuit breakers and relays.

Section	Topic	Element
34.6 Transformer testing and maintenance	**346.1 Inspection prior to installation**	3461.1 Tests of the dielectric strength of the oil 3461.2 Pressure tests 3461.3 Temperature gauges 3461.4 Core and coil drying
	346.2 Fluid maintenance	3462.1 Fluid indicators 3462.2 Handling precautions when: adding, sampling, testing, filtering
	346.3 Leaks	3463.1 Condensation of moisture 3463.2 Effect of weather conditions 3463.3 Dust contamination 3463.4 Sealing methods
	346.4 Moisture removal	3464.1 Drying with the oil in the tank 3464.2 Drying with the oil removed 3464.3 Internal heat 3464.4 External heat

UNIT: 3.4 Distribution Systems

Topic	Element	Cross-Reference	Technical Terms
1 Inspection prior to installation	3461.1 Tests of the dielectric strength of the oil	171.7	Dielectric
	3461.2 Pressure tests	1115.3	
	3461.3 Temperature gauges		
	3461.4 Core and coil drying		Sediment
2 Fluid maintenance	3462.1 Fluid indicators		
	3462.2 Handling precautions when: adding, sampling, testing, filtering		
3 Leaks	3463.1 Condensation of moisture	1115.2	Oxidation Ambient
	3463.2 Effect of weather conditions		
	3463.3 Dust contamination		
	3463.4 Sealing methods		
4 Moisture removal	3464.1 Drying with the oil in the tank		
	3464.2 Drying with the oil removed		
	3464.3 Internal heat		
	3464.4 External heat		

Regulations	Suggestions for Student Activity	
	TRANSFORMER TESTING (P) (O) • perform a series of basic tests required on transformers before they are put into service.	A hydro maintenance chart shop. Discussions in class shoul overhead and underground
		Although a transformer rec electrical apparatus, neglec to serious trouble. Oxidation and moisture con the ambient temperature wi
		Rubber or materials contai or gaskets.

gestions for Student Activity	Discussion
TESTING (P) (O) es of basic tests required on transformers before service.	A hydro maintenance chart could be used to check a transformer in the shop. Discussions in class should outline the advantages and disadvantages of overhead and underground services.
	Although a transformer requires less care than almost any other type of electrical apparatus, neglect of certain fundamental requirements may lead to serious trouble. Oxidation and moisture contaminate the oil. Operating transformers above the ambient temperature will prevent condensation.
	Rubber or materials containing rubber should not be used for stoppers or gaskets.

DIVISION 3: Installation and Maintenance

UNIT: 3.5 A.

Section	Topic	Element
35.1 Elements of a motor control system	**351.1 Regulations and definitions**	3511.1 Code book 3511.2 Motor control references 3511.3 Block diagram of circuits
	351.2 Disconnecting means	3512.1 Types of switches and breakers 3512.2 Requirements and regulations 3512.3 Sizes and ratings 3512.4 Location considerations
	351.3 Overcurrent protection	3513.1 Rating determination 3513.2 Methods and types
	351.4 Motor controllers	3514.1 Location 3514.2 Types 3514.3 Purpose 3514.4 Sizes and ratings
	351.5 Overload protection	3515.1 Regulations 3515.2 Purpose 3515.3 Types 3515.4 Resetting 3515.5 Locations
	351.6 Considerations in the choice of a control system	3516.1 Available voltages 3516.2 Environment 3516.3 Functions 3516.4 Determination of size
	351.7 Combination starter	3517.1 Physical characteristics 3517.2 Advantages

UNIT: 3.5 A. C. Motor Controls

Topic	Element	Cross-Reference	Technical Terms
1 Regulations and definitions	3511.1 Code book 3511.2 Motor control references 3511.3 Block diagram of circuits	3.2	Motor controller Overcurrent protection Overload protection Inherent protection
2 Disconnecting means	3512.1 Types of switches and breakers 3512.2 Requirements and regulations 3512.3 Sizes and ratings 3512.4 Location considerations	3414.5 3414.1 342.3	Non-fused Arc shield
3 Overcurrent protection	3513.1 Rating determination 3513.2 Methods and types	3414.4 342.3	Electro-mechanical device Time delay Dual element High rupturing capacity
4 Motor controllers	3514.1 Location 3514.2 Types 3514.3 Purpose 3514.4 Sizes and ratings	142.2 362.1	Across-the-line Undervoltage protection Undervoltage release Thermal cutout Integral protection device
5 Overload protection	3515.1 Regulations 3515.2 Purpose 3515.3 Types 3515.4 Resetting 3515.5 Locations	3414.5 35.2	Sustained overload Bi-metal Thermal cutout Reset Dashpot Overload relay Ambient temperature Inverse time characteristics Eutectic protection
6 Considerations in the choice of a control system	3516.1 Available voltages 3516.2 Environment 3516.3 Functions 3516.4 Determination of size	1.4	Hazardous location General purpose enclosure Combination starter
7 Combination starter	3517.1 Physical characteristics 3517.2 Advantages		

Regulations	Suggestions for Student Activity	Di
OEC — Section 28, Appendix B		
OEC — Section 14 OEC — Section 28		The student should become f handle locking mechanisms and the introduction of the motor co instruction around the line diagr of the Ontario Electrical Code.
OEC — Section 28 OEC — Section 14		
OEC — Section 28	**MOTOR CONTROL SYSTEM (E)** • study the system elements of a motor control circuit to show their inter-relationship, significance and functions. (A combination starter may be used.)	A combination switch and contr study of the elements of a moto
OEC — Section 28	**OVERLOAD PROTECTION (E)** • investigate the operation of the tripping characteristics of overload devices.	
OEC — Section 28		

ons for Student Activity	Discussion
	The student should become familiar with the disconnecting door and handle locking mechanisms and their respective safety application. During the introduction of the motor control elements, the teacher should build the instruction around the line diagrams as presented on page 413, Appendix B, of the Ontario Electrical Code.
YSTEM (E) lements of a motor control circuit to show , significance and functions. (A combina- ed.)	A combination switch and controller serves as excellent equipment for the study of the elements of a motor control system.
ION (E) ation of the tripping characteristics of over-	

DIVISION 3: Installation and Maintenance

UNIT: 3.5 A.

Section	Topic	Element
35.2 Conductors and protection devices	**352.1 Regulations**	3521.1 Protection required 3521.2 Conductor calculations
	352.2 Fuses versus time delay fuses	3522.1 Construction and physical characteristics 3522.2 Calculations based on code book 3522.3 Employing a fustat for single-phase motors 3522.4 Supporting devices for fustat inserts 3522.5 Advantages of fuses and time-delay fuses
	352.3 Circuit breakers; sizes and types	3523.1 Time limit versus instantaneous action 3523.2 Determination of setting
	352.4 Motor grouping	3524.1 Calculations of feeders, sub-feeders and conduit 3524.2 Fuse sizes
35.3 Manual starting switches	**353.1 Single-phase across-the-line motor starting switches**	3531.1 Physical characteristics 3531.2 Size and voltage rating 3531.3 Applications
	353.2 Single-phase reversing drum controllers	3532.1 Types of drum switches 3532.2 Internal connections 3532.3 Typical circuits 3532.4 Applications
	353.3 Three-phase manual across-the-line starters	3533.1 Theory of operation 3533.2 Sizes and ratings 3533.3 Applications
	353.4 Three-phase reversing drum controllers	3534.1 Theory of operation 3534.2 Sizes and ratings 3534.3 Applications

UNIT: 3.5 A. C. Motor Controls

Topic	Element	Cross-Reference	Technical Terms
2.1 Regulations	3521.1 Protection required 3521.2 Conductor calculations		
.2 Fuses versus time delay fuses	3522.1 Construction and physical characteristics 3522.2 Calculations based on code book 3522.3 Employing a fustat for single-phase motors 3522.4 Supporting devices for fustat inserts 3522.5 Advantages of fuses and time-delay fuses	3414.2 3414.4	Tamper resistant Fustat
.3 Circuit breakers; sizes and types	3523.1 Time limit versus instantaneous action 3523.2 Determination of setting	142.2	Tripping elements Magnetic breaker Thermal breaker
2.4 Motor grouping	3524.1 Calculations of feeders, sub-feeders and conduit 3524.2 Fuse sizes	342.3	
.1 Single-phase across-the-line motor starting switches	3531.1 Physical characteristics 3531.2 Size and voltage rating 3531.3 Applications	1741.1	Across-the-line starter
3.2 Single-phase reversing drum controllers	3532.1 Types of drum switches 3532.2 Internal connections 3532.3 Typical circuits 3532.4 Applications	17.4 36.2	Drum controller Clockwise Counter-clockwise
.3 Three-phase manual across-the-line starters	3533.1 Theory of operation 3533.2 Sizes and ratings 3533.3 Applications	1731.3	Single-phasing
3.4 Three-phase reversing drum controllers	3534.1 Theory of operation 3534.2 Sizes and ratings 3534.3 Applications	17.3 36.2	Triple pole, double throw

Regulations	Suggestions for Student Activity	Discu
OEC — Section 28		
OEC — Section 28 OEC — Section 14	**TIME-DELAY FUSES (A)** • study the application and design of time-delay fuses. **INSTALLATION OF A SINGLE-PHASE MOTOR (P)** • connect a single-phase motor and select the correct overload heater coil.	
OEC — Section 14	**OVERLOAD RELAY (P)** • illustrate the operation of an overload relay which energizes an indicator light.	The topic of motor grouping provide calculating feeder and conduit sizes
OEC — Section 28		
OEC — Section 28 OEC — Section 14		The instructor should outline the we line starter without a "no-voltage" mine the location of motor windings be a meaningful exercise.
OEC — Section 28	**SINGLE-PHASE MOTOR REVERSING (P)** • wire a drum controller which is used to reverse a single-phase motor.	The students must learn the stan switches. Advantages and limitations of the m discussed during the study of this ty
C.S.A.	**THREE-PHASE MANUAL STARTERS (P)** • plan and construct three-phase manually controlled motor circuits. These circuits should follow approved wiring practices and allow the students experience in selected fuse and heater coil sizes.	
	OVERLOAD PROTECTION (E) • demonstrate single-phasing and its results on overload protection by removing a fuse from the above three-phase motor project while the motor is in operation.	

estions for Student Activity	Discussion
ES (A) cation and design of time-delay fuses.	
F A SINGLE-PHASE MOTOR (P) le-phase motor and select the correct overload	
Y (P) peration of an overload relay which energizes an	The topic of motor grouping provides an opportunity to assign problems in calculating feeder and conduit sizes.
	The instructor should outline the weakness of the single-phase across-the-line starter without a "no-voltage" release. Use of a multi-tester to determine the location of motor windings and to analyze a drum controller would be a meaningful exercise.
OTOR REVERSING (P) ntroller which is used to reverse a single-phase	The students must learn the standard terminal identification on motor switches. Advantages and limitations of the manual across-the-line starter should be discussed during the study of this type of controller.
ANUAL STARTERS (P) uct three-phase manually controlled motor cir- uits should follow approved wiring practices dents experience in selected fuse and heater	
ECTION (E) ngle-phasing and its results on overload protec- a fuse from the above three-phase motor otor is in operation.	

Section	Topic	Element
35.4 Magnetic across-the-line starters	**354.1 Internal circuits**	3541.1 Pre-wiring within the starter 3541.2 Identification and function of internal parts 3541.3 Numbering sequence for three auxiliary connections 3541.4 Dual voltage coils
	354.2 Related control devices	3542.1 Types of push buttons 3542.2 Hand, automatic and off control 3542.3 Pilot control by thermostats, aquastats and sensing devices 3542.4 Jogging switches 3542.5 Control transformers 3542.6 Limit switches and electrical interlocks
	354.3 Reversing magnetic starters	3543.1 Two magnetic contactors employing one set of overload relays 3543.2 Methods of rotation control 3543.3 Single and multiple contact push buttons 3543.4 Electrical and mechanical interlocks
35.5 Reduced voltage starters	**355.1 Purpose**	3551.1 Applications 3551.2 Supply voltage factor 3551.3 Advantages
	355.2 Features	3552.1 Sizes 3552.2 Methods of dissipating heat 3552.3 Percentage taps 3552.4 Manual versus automatic

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UNIT: 3.5 A. C. Motor Controls

Topic	Element	Cross-Reference	Technical Terms
Internal circuits	3541.1 Pre-wiring within the starter		Sealing Shaded pole Solenoid
	3541.2 Identification and function of internal parts	112.5	
	3541.3 Numbering sequence for three auxiliary connections		
	3541.4 Dual voltage coils		
Related control devices	3542.1 Types of push buttons		Transfer stations Sequence operation Limit switches Mechanical interlocks Electrical interlocks Aquastats Thermostats Jogging Control transformer
	3542.2 Hand, automatic and off control		
	3542.3 Pilot control by thermostats, aquastats and sensing devices	142.2	
	3542.4 Jogging switches		
	3542.5 Control transformers	17.1	
	3542.6 Limit switches and electrical interlocks		
Reversing magnetic starters	3543.1 Two magnetic contactors employing one set of overload relays	112.5	Plugging
	3543.2 Methods of rotation control		
	3543.3 Single and multiple contact push buttons	142.2	
	3543.4 Electrical and mechanical interlocks		
Purpose	3551.1 Applications		Taps Open and closed transition
	3551.2 Supply voltage factor		
	3551.3 Advantages	171.10	
Features	3552.1 Sizes		Percentage tap
	3552.2 Methods of dissipating heat		
	3552.3 Percentage taps		
	3552.4 Manual versus automatic	1.4	

Regulations	Suggestions for Student Activity	
	FORWARD-REVERSE SWITCHING OF MOTORS (P) • connect a forward-reversing magnetic starter, the circuit to include directional indicating lights. The circuit should be developed to incorporate the use of limit switches.	Across-the-line magnetic st regard to design and constru attempted will depend on th should include manual contr with auxiliary devices. As t encouraged to design more c
	INTEGRATED MOTOR CONTROL CIRCUITS (P) • wire variations of circuits involving: one push-button station, two push-button stations, start-stop job station, combinations of push-button stations, maintained contacts, transfer stations employing automatic operation from sensing devices and indicator lights.	
		Reversing controllers can b cuits, thereby illustrating a s
Local supply authority OEC — Section 12 Section 28	**REDUCED VOLTAGE STARTERS (P) (O)** • wire and analyze the operation of reduced voltage starters of several types.	Students should become fa reduced-voltage starting. La dents from understanding the methods used to satisfy local as a research project.
C.S.A. Canadian Electrical Manufacturers Association		The local supply authority wi reduced voltage starters mus

gestions for Student Activity	Discussion
RSE SWITCHING OF MOTORS (P) vard-reversing magnetic starter, the circuit to in- indicating lights. The circuit should be de- orate the use of limit switches.	Across-the-line magnetic starter circuits offer many possibilities both in regard to design and construction of control circuitry. The projects that are attempted will depend on the availability of equipment. At first, circuits should include manual control with start-stop stations, or maintain contact with auxiliary devices. As the student develops confidence he should be encouraged to design more complex circuits.
OTOR CONTROL CIRCUITS (P) s of circuits involving: one push-button station, stations, start-stop job station, combinations of ions, maintained contacts, transfer stations atic operation from sensing devices and indi-	Reversing controllers can be incorporated into standard three-phase circuits, thereby illustrating a simple, economical method of motor reversing.
AGE STARTERS (P) (O) yze the operation of reduced voltage starters of	Students should become familiar with the principles and advantages of reduced-voltage starting. Lack of equipment should not prevent the students from understanding the problems of full-load voltage starting and the methods used to satisfy local requirements. This topic could be undertaken as a research project. The local supply authority will determine at what horsepower motor rating reduced voltage starters must be used.

Section	Topic	Element
35.5 Reduced voltage starters (continued)	**355.3 Automatic compensators**	3553.1 Theory of operation 3553.2 Tap changing methods 3553.3 Three auto transformers — method 3553.4 Two auto transformers — method 3553.5 Automatic timed control starter 3553.6 Open and closed transition 3553.7 Timing mechanisms
	355.4 Wye-delta starters	3554.1 Principle of operation 3554.2 Advantages and disadvantages 3554.3 Typical applications

UNIT: 3.5 A. C. Motor Controls

Topic	Element	Cross-Reference	Technical Terms
Automatic compensators	3553.1 Theory of operation 3553.2 Tap changing methods 3553.3 Three auto transformers — method 3553.4 Two auto transformers — method 3553.5 Automatic timed control starter 3553.6 Open and closed transition 3553.7 Timing mechanisms	171.10 171.13	Escapement devices Compensator
Wye-delta starters	3554.1 Principle of operation 3554.2 Advantages and disadvantages 3554.3 Typical applications	171.12	Wye-delta starting

Regulations	Suggestions for Student Activity	Di
OEC — Section 28 Table 29		
C.E.M.A.		This method of speed control motor starting.

gestions for Student Activity	Discussion
	This method of speed control is becoming more common as a method of motor starting.

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DIVISION 3: Installation and Maintenance

UNIT: 3.6 Elec

Section	Topic	Element
36.1 Diagnosis of circuit faults	**361.1 Circuit analysis and tests**	3611.1 Tests for: shorts, opens, grounds and continuity 3611.2 Leakage tests 3611.3 Voltage, amperes and resistance measurement to assist analysis of malfunctions 3611.4 Wattage measurement and calculations
	361.2 Test equipment	3612.1 Wiggenton type 3612.2 Meggers 3612.3 Ringers 3612.4 Multimeters 3612.5 Ammeters and clamp-on ammeters 3612.6 Wattmeters
36.2 Industrial equipment	**362.1 Controllers**	3621.1 Circuit analysis 3621.2 Coil tests 3621.3 Contact maintenance 3621.4 Overload relay malfunctions
	362.2 Motor circuits	3622.1 Circuit analysis 3622.2 Single-phase starting switch; troubles and correction 3622.3 A.C. capacitor tests 3622.4 Bearings: types and applications, replacing 3622.5 Rotor tests: balancing 3622.6 Stator tests: shorts, opens, polarity

d Maintenance

UNIT: 3.6 Electrical Maintenance

Topic	Element	Cross-Reference	Technical Terms
1 Circuit analysis and tests	3611.1 Tests for: shorts, opens, grounds and continuity	111.4	Leakage
	3611.2 Leakage tests	346.3	
	3611.3 Voltage, amperes and resistance measurement to assist analysis of malfunctions	12.1 111.6	Insulation resistance
	3611.4 Wattage measurement and calculations		
2 Test equipment	3612.1 Wiggenton type		Megger
	3612.2 Meggers	12.1	
	3612.3 Ringers		
	3612.4 Multimeters		
	3612.5 Ammeters and clamp-on ammeters		
	3612.6 Wattmeters		
Controllers	3621.1 Circuit analysis	111.4	Contact chatter
	3621.2 Coil tests	351.4	Oxidize
	3621.3 Contact maintenance	1422.3	Contact pitting
	3621.4 Overload relay malfunctions	112.4 112.5	
2 Motor circuits	3622.1 Circuit analysis	111.4	
	3622.2 Single-phase starting switch; troubles and correction	17.4	
	3622.3 A.C. capacitor tests	153.1	
	3622.4 Bearings: types and applications, replacing	153.2	
	3622.5 Rotor tests: balancing		Out-of-round
	3622.6 Stator tests: shorts, opens, polarity		Balance Internal shorts

Regulations	Suggestions for Student Activity	Disc
		Section 36.1 will be integrated thr used by the students in experimen Appliance servicing should be an appliances being brought into the
	INSULATION TESTS (E) • measure the resistance of moist and dry asbestos-insulated wire, using meggers.	
	MOTOR CONTROL CIRCUITS (P) • locate typical faults in a variety of types of motor controls.	Emphasis should be placed on a Frequent use of the manufacturers The project of motor control circui
	SINGLE-PHASE MOTOR STARTING SWITCHES (A) • study the types and applications of starting switches and their mechanisms.	
	SINGLE-PHASE MOTORS (P) • trouble-shoot and correct faults on single-phase motors.	A variety of used fractional horse shop for testing and trouble shooti

stions for Student Activity	Discussion
	Section 36.1 will be integrated throughout the course as test equipment is used by the students in experiments and projects. Appliance servicing should be an important part of the I. & M. course, with appliances being brought into the shop to be repaired.
S (E) sistance of moist and dry asbestos-insulated s.	
CIRCUITS (P) ults in a variety of types of motor controls.	Emphasis should be placed on a systematic check on the circuit faults. Frequent use of the manufacturers service manuals should be encouraged. The project of motor control circuits should be integrated with Unit 3.5.
TOR STARTING SWITCHES (A) and applications of starting switches and their	
TORS (P) correct faults on single-phase motors.	A variety of used fractional horsepower motors should be available in the shop for testing and trouble shooting.

Section	Topic	Element
36.2 Industrial equipment (continued)	**362.3 Preventive maintenance**	3623.1 Bearing lubrication 3623.2 Servicing requirements and environmental conditions 3623.3 Motor operating temperatures 3623.4 Belt tension and bearing types 3623.5 Single-phase motor and polyphase motor maintenance comparison
36.3 Domestic appliances	**363.1 Water heater**	3631.1 Methods of supply and control 3631.2 Local by-laws 3631.3 Single heater unit 3631.4 Two-heater unit, flip flop thermostats
	363.2 Ranges	3632.1 Circuit analysis 3632.2 Determination of the circuit requirements for counter top-wall oven unit 3632.3 Multi-heat switching

UNIT: 3.6 Electrical Maintenance

Topic	Element	Cross-Reference	Fundamentals
Preventive maintenance	3623.1 Bearing lubrication	173.3	Sleeve bearings Radial load Thrust load
	3623.2 Servicing requirements and environmental conditions		
	3623.3 Motor operating temperatures		Ambient temperature Vapour proof Explosion proof Hermetically sealed Variable patch pulleys Centrifugal switch
	3623.4 Belt tension and bearing types		
	3623.5 Single-phase motor and polyphase motor maintenance comparison	173.4	
Water heater	3631.1 Methods of supply and control	111.6	Flip-flop thermostat Immersion Strap-on Circulation
	3631.2 Local by-laws		
	3631.3 Single heater unit		
	3631.4 Two-heater unit, flip flop thermostats		
Ranges	3632.1 Circuit analysis	111.4	Multi-heat switch
	3632.2 Determination of the circuit requirements for counter top-wall oven unit	111.6 341.3	
	3632.3 Multi-heat switching		

Technical Terms	Suggestions for Student Activity	Disc
	MOTOR MAINTENANCE (P) • maintain all motors in the technical department on a scheduled basis.	Preventive motor maintenance m school. Maintenance charts shoul
Supply authority	**APPLIANCE THERMOSTATIC CONTROL (P)** • demonstrate the operation of a simple contact thermostat. A further study would include the operation of a multi-contact thermostat and the circuitry as related to water heaters.	The shop equipment should inclu equipment has a great deal of va with the integration of electrical a
	MULTI-HEAT SWITCHES (P) • develop a circuit using a multi-heat switch and lamps to indicate switching and heating sequences.	

tions for Student Activity	Discussion
ANCE (P) rs in the technical department on a scheduled	Preventive motor maintenance might include the motors throughout the school. Maintenance charts should be kept on all motors.
OSTATIC CONTROL (P) operation of a simple contact thermostat. A d include the operation of a multi-contact circuitry as related to water heaters.	The shop equipment should include at least two major appliances. This equipment has a great deal of value in electrical circuitry analysis along with the integration of electrical and mechanical principles.
CHES (P) using a multi-heat switch and lamps to indicate ng sequences.	

Section	Topic	Element
36.3 Domestic appliances (continued)	**363.3 Clothes dryers**	3633.1 Determination of circuit requirements
		3633.2 Neutral conductor behaviour
		3633.3 Safety interlocking devices in the dryer
		3633.4 Analysis of dryer problems
	363.4 Oil burners	3634.1 Branch circuit requirements
		3634.2 Safety regulations
		3634.3 Low-voltage circuitry
		3634.4 Primary and limit controls
		3634.5 Oil burner circuitry

aintenance

UNIT: 3.6 Electrical Maintenance

pic	Element	Cross-Reference	Technical Terms
hes dryers	3633.1 Determination of circuit requirements	111.6	
	3633.2 Neutral conductor behaviour		
	3633.3 Safety interlocking devices in the dryer		Safety interlock
	3633.4 Analysis of dryer problems		
burners	3634.1 Branch circuit requirements	111.4	Limit control Ignition transformer Airstats Protectostat Mercury switch
	3634.2 Safety regulations		
	3634.3 Low-voltage circuitry		
	3634.4 Primary and limit controls		
	3634.5 Oil burner circuitry		

Regulations	Suggestions for Student Activity	D
	PROGRAMMED SWITCHING (P) • study a washer or dryer switch and its related circuitry.	The intent is not to teach appl with typical circuits and their re should, however, be in the room

gestions for Student Activity	Discussion
SWITCHING (P) r or dryer switch and its related circuitry.	The intent is not to teach appliance repair, but to familiarize the student with typical circuits and their respective analysis. Some types of appliances should, however, be in the room.

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